

SCIENTIFIC RIDDLES

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P R E F A C E

All Nature bristles with marks of interrogation—among the grass and the petals of flowers, amidst the feathers of birds and the hairs of mammals, on mountain and moorland, in sea and sky—everywhere. It is one of the joys of life to discover these marks of interrogation, these unsolved and half-solved problems, and to try to answer their questions. Some of them are being answered every day, and many of the larger ones have been so well answered that we are warranted in speaking of the intelligibility of Nature; but the solving of one riddle often discloses others, and so the quest continues. It is the chief end of science to make things clearer, but it is one of its educative aims to foster the inquisitive spirit, and that is the aim of this book, to select a few fair samples of the thousand-and-one scientific riddles, and to discuss them a little so that they suggest others—and others—to the increase of the interest and efficiency of our life.

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INTRODUCTORY

WHAT ARE SCIENTIFIC RIDDLES?

It is a step towards clearness to distinguish different types of "unsolved problems."

(1) There are those in regard to which there is a paucity of facts, as may be illustrated by the problem of homing in migratory birds. How do migrants find their way in spring from the Gold Coast to Scotland, their native land? As facts accumulate we come nearer an answer.

(2) Then there are problems in regard to which facts are abundant, yet the central fact, the keystone of the arch, is lacking. Thus we know a great deal about nervous impulses, but we do not yet know wherein they precisely consist. There are volumes of facts about sex, but we do not yet know the essential difference between maleness and femaleness.

(3) Another type of unsolved problem arises when our inquisitiveness outruns our education. Everyone knows that gravitation is the mutual attraction between masses of matter of considerable size, and everyone understands Newton's Law, that the strength of the pull varies directly as the product of the masses concerned, and inversely as the square of their distances apart. But when we try to get in behind the Law and inquire into the reason for the mutual attraction, or try to bring gravitation into line with other forces of Nature, we encounter difficulties with which few of us are able to cope. We understand what the Law of Gravitation states, but we do not understand the modern *theory* of gravitation, unless we understand Einstein's general theory of relativity, which few of us do.

A fourth kind of unsolved problem is largely of our

own making; though we must not say this too soon or too dogmatically. We often make trouble for ourselves by too persistently trying to explain something (e.g. Life) in terms of something else (e.g. Matter and Energy). Our perplexed friend says that he cannot understand how the brain gives rise to mind. But this is a pseudo-problem, if it means attempting to explain the mind in terms of, say, metabolism, a fraction of reality that we only know by means of our mind. Moreover, "mind" and "brain" are incommensurable, for mind is not molecular; and by no jugglery can we describe a poem in terms of protoplasm.

In the same way it may be a pseudo-problem to ask: What is Life? if we ask the question with the expectation of giving an adequate account of this characteristic kind of activity in terms of chemistry and physics. While we must, of course, press on with the chemistry and physics of the living body, which have already yielded invaluable results, we have no warrant for being sanguine of success in explaining life in terms of anything else. It may be an irreducible, just as mind is.

In pseudo-problems we have not learned to state the problem in an answerable way; and the difficulty of doing this should make us humble and patient. When we ask: What is the relation between mind and body?—a perennial puzzle which has rewarded inquiry since the time of Aristotle—we have a shrewd suspicion that the lack of agreement among courageous answerers, who have been among the wisest of men, must be partly due to a failure to ask the question in the right way. Yet it is also possible that the question is too difficult for man's intelligence. It may be a *horizon problem*, so elusive for our faculties that it recedes as we approach it. We get nearer it, in a way; yet asymptotically.

: One other caution may be excused—for the whole

quest is very serious. It is this, that we all become more and more accustomed to asking scientific questions, and expecting, sooner or later, definite scientific answers. How does science account for a rainbow? What are the Northern Lights? How does a bee find its way home? How does a hen's egg become a chick? How is it that we remember? and What happens when we are moved with righteous anger? These are more or less answerable scientific questions, but in the midst of them someone asks: What is the meaning of the Universe? What is the purpose of evolution? Is there a spiritual world? and so on.

The outcome of these irrepressible questions is often puzzlement, and not merely because they are obviously very difficult, but because we make the mistake of expecting scientific answers, which, from the nature of the case, is an expectation bound to be disappointed.

For the question *Why?* (in the sense, What is the meaning or purpose of this or that great process or event?) is never asked by science, since it is a question that cannot be answered by scientific methods. Science is a system of empirical description, based on observation and experiment, couched in the simplest and tersest terms, and verifiable by all normally constituted minds who can use the methods. But the moment we ask such a question as: Is there a design in evolution? or Can personality survive bodily death? we are *beyond science*, though not necessarily off the pathway to Reality or off the way to Truth.

PART I

CHAPTER I

HOW DID LIFE BEGIN?

It is quite certain that there was a long lifeless period in the history of the earth—for the temperature was far too high to admit of the existence of any living creatures such as we know—built up of protoplasm in a colloidal state with at least seventy-five per cent. of water. As we cannot even picture any other kind of living creature, we need not discuss the possibility that life had some other form or expression when the earth was a nebulous mass, or even when its cooling crust was still too hot to allow of the presence of water in a liquid form. If we are so inclined we can people the aboriginal earth with “pre-bions”—living creatures antecedent to the simplest forms we know—but we cannot give them any actuality; and to play with inconceivable phantoms is a sheer waste of time. No one has succeeded in concretely imagining any organism that could live in the fire-mist!

But at some date to which cosmogonists can approximately argue back—perhaps 1,000,000,000 years ago—the crust of the earth became cool enough to be a cradle for life; and it is not a waste of time to ask the question—even if we cannot answer it—

HOW DID ORGANISMS BEGIN TO BE UPON THE EARTH?

In everyday life we often give replies that are not answers. A Scot's reply is often another question, and the French have a rather savage phrase, “parler pour ne rien dire,” talking so as to say nothing. Some of the replies to our difficult question—*How did organisms begin?*—are more than evasions or insincerities, but they are not answers.

Thus some would reply that living creatures began by a divine Fiat. As Theodore Parker said: "The universe, broad and deep and high, is a handful of dust which God enchants. He is the mysterious magic which possesses the world." Personally we regard this as true, but our present question is a *scientific* one: Is it possible to give any description of the verifiable empirical factors which may have led to the emergence of living creatures upon the earth? An acceptance of a philosophical or religious interpretation of the origin of life does not relieve us from the responsibility of tackling the scientific problem.

Another reply that commands our sympathy must also be set aside as no answer. It is the frank confession, Ignoramus; and it must be conceded at once that no one at present *knows* how living creatures came to be on the earth. Many years have passed since Huxley expressed his scientifically reasoned opinion that the original simplest forms of life arose naturally from non-living matter; but he ended by stating plainly that he did not *know*. The problem is so difficult and the clues are so vague that we can well understand those who shake their heads and refuse to express any opinion. This agnostic position is at present not unreasonable, but it is not progressive; and we have to be careful not to allow Ignoramus to become Ignorabimus. It is dogmatic to call the problem insoluble, for the probability is that when we learn to put the question rightly, the answer will come.

It has been repeatedly suggested that germs of life may have reached the cooled earth from elsewhere—encased in the crevices of a meteorite or wafted along with cosmic dust. That this suggestion is not to be hastily smiled away is evident from the fact that it came from Kelvin and Helmholtz, Richter and Arrhenius, all well aware of the difficulties involved. To the objection that

the hypothetical germs of life would be killed by extremes of temperature on their journey, it is answered that experiments have shown that simple forms of life sometimes survive great heat and great cold and otherwise inhospitable conditions. More serious, perhaps, is the objection that no one can give a name to the other world from which the germs of life might have come; and it is by no means certain that either Venus or Mars, to mention the two most probable homes of life, is really tenanted by organisms. Thus the hypothesis of life from another world is very much in the air, and while it is a scientific and positive suggestion, we must leave it aside in our present inquiry, for the simple reason that it only shelves the problem. If germs of life came from elsewhere, how did they arise in their original cradle?

From before Aristotle till after Harvey, and including both of them, a belief in spontaneous generation was widespread. Men saw insects appearing in the dead flesh and in the rain-water barrel; what more natural than the inference that the living might arise from the not-living? Even after the sagacious Florentine physician, Redi, showed, about the middle of the seventeenth century, that insects never appeared in dead flesh that was covered with a thin cloth, he still thought that spontaneous generation might occur in some other cases, like intestinal worms in man. Even after the microscope revealed the previously unknown, because more or less invisible, eggs or germs of many different kinds of animals, the belief in spontaneous generation lingered. It did not practically die even after Tyndall and Pasteur gave it a theoretical death-blow! One reason was that naturalists had not yet learned either the intricacy or the specificity of most organisms, for a realization of these two facts makes it impossible for the modern investigator

to imagine that any ordinary living creature could arise from anything but another of the same kind. The saying, "omne vivum e vivo" is in a general way unanimously accepted; but we are even more confident in asserting that every organism arises from a parent organism of the same kind.

It is safe to say at present that there is no experimental evidence that even the simplest organisms can arise except from similar organisms, but this experimental conclusion must not be made into a dogma. The absence of any present-day evidence of "spontaneous generation," the origin of the living from the not-living, does not warrant us in saying that it never occurred, or that it never will occur. Even to-day it may be occurring, for there are organisms too small to be detected with the ordinary microscope, and it is *possible* that some of these, or others like them, may be appearing *de novo* to-day in unrecognized propitious conditions, and that they may be very short-lived—disappearing, as they appeared, all unbeknownst.

Practically, however, no one has a good word to say for present-day abiogenesis or spontaneous generation, so we need not delay longer over this ancient heresy, beyond noting that the problem of the origin of life did not weigh on those who imagined, like Lucretius or even Milton, that animals as big as lions could paw their way out of Mother Earth.

How did living creatures begin? The only scientific answer in the field is the hypothesis that very simple organisms arose long ago from non-living materials by a process of natural synthesis. This is a bold hypothesis not to be lightly held; for there are deep differences between the living and the non-living, and between the quick and the dead. The hypothesis of the occurrence of spontaneous generation long ago has to meet the

following objections: (1) If this abiogenesis occurred long ago, why does it not occur now? It may be answered that the original favourable conditions have not recurred. But, as we have said, another answer might be the question: Is it certain that spontaneous generation never recurs to-day?

(2) Another objection has been found in the rarity of synthetic processes in natural conditions on the earth to-day. If living creatures were once synthesized from some carbonaceous colloidal slime activated by ferments, might one not expect to find syntheses of organic compounds still going on in natural conditions to-day? It might be too much to expect the recurrence of spontaneous generation, but might one not expect to find steps in that direction? But the fact is that a natural synthesis of organic compounds, *apart from life*, is conspicuous by its rarity in present-day conditions.

(3) Another objection to the hypothesis of the origin of the living from the not-living calls attention to the difference between the synthesis of carbon compounds and the making of a living creature, however simple. Even if we knew how carbohydrates, fats, proteins, and other carbon compounds might have arisen long ago by natural synthesis, even a mixture of these would not necessarily result in living matter, still less in a living creature—able to act and yet persist, able to grow and multiply. This seems to us a reasonable objection—though not a fatal one—to the theory which we personally favour. Our method is to state pros and cons; and the third objection is a “con” which should prevent anyone from being too glib or facile with the hypothesis. Let us try to meet the difficulty.

(A) All living creatures are built up of proteins and other carbon compounds. Many of these have been artificially built up by the synthetic chemist, who can make,

for instance, sugar, alcohol, indigo, salicylic acid, amino-acids, and such rarities as the hormones known as thyroxin (naturally made by the thyroid gland) and adrenalin (naturally made by the supra-renal bodies).

During the last hundred years all sorts of things, whose manufacture was previously held to be a prerogative of life, have been made artificially. The most essential constituents of protoplasm are proteins; proteins are complexes of amino-acids; amino-acids have been made artificially. Why, then, may not the first protoplasm have been built up long ago in some *natural* laboratory?

(B) When the earth began to get a cool crust, on which water-vapour condensed, there was an abundance of carbon dioxide in the atmosphere, and occasional thunderstorms would bring down ammonium nitrite or the like into the sunlit pools. It is possible that the illumination of the water, with its content of carbon dioxide, would result in the synthesis of simple carbon compounds such as formaldehyde, and that these would combine with ammonium nitrite or the like to form simple nitrogenous carbon compounds—the first steps towards the amino-acids, which have been called the building-stones of life.

(C) Very suggestive are the experiments of Baly and his collaborateurs who obtained formaldehyde (CH_2O) by subjecting water with carbonic acid gas to prolonged illumination from a mercury vapour lamp which gives out light with very short wave-lengths. With further illumination Baly got sugar; and he also induced the formaldehyde to combine with nitrites, thus forming nitrogenous carbon compounds approaching those of living matter. Similar results were obtained by using ordinary sunlight in the presence of a "metallic photocatalyst," that is to say, a metallic substance which made the energy of light more available. Confirmations

and extensions are eagerly looked for, for the importance of Professor Baly's work is that he has approached the confines of living matter without using any material or means not readily available in Nature.

(D) It is often said that the achievements of the synthetic chemist are irrelevant unless we can indicate something in Nature that would take his place in building up living matter without the help of life. But the chemists themselves tell us of many things that might have been happening at or near the surface of the earth before the dawn of life.

(1) The condensed water-vapour would act on the carbides (e.g. of calcium and iron) in the warm rock crust, and set free marsh gas (CH_4) and other hydrocarbons; (2) under the influence of light and with the help of evaporation, various carbon compounds, even up to acetic acid, might be formed; (3) electric discharges in the air would dissociate evaporated chlorides and liberate free chlorine—an effective agent in change, and would on the other hand form compounds like ammonium nitrite, just as man does to-day when he synthesizes artificial fertilizers out of the atmosphere; (4) not only would evaporations from small pools tend to concentrate the acids and other substances that were a-forming, but certain metallic substances may have acted as catalysts, bringing different substances into very close quarters, and anticipating fermentation; (5) when molecules began to aggregate into particles suspended in the water there began to be colloidal states of organic matter, and life drew nearer.

These and many other considerations make the hypothesis of the natural synthesis of protoplasm much more plausible than it was in Huxley's day.

As we have said, it is scientifically possible to think of the natural synthesis of amino-acids and other sub-

stances that go to the making of the physical basis of life. But even when we picture the first organisms as microscopically minute, very simple in structure, and very short-lived, they stand apart—with all the uniqueness of a new expression of reality. They were able to act without destroying themselves; they could balance accounts of upbuilding and down-breaking for the few days of their life's span; they probably fed on the failures to reach their own climax; they were able to grow and multiply and evolve. If they actually emerged from the not-living, then the not-living is a subtler thing than our forefathers supposed; and everyone knows that the old idea of the deadness of non-living matter has gone by the board.

It is of the very essence of evolution to be *integrative*, to build up higher and higher wholes, and, as General Smuts puts it: "Matter, Life, and Mind, so far from being discontinuous and disparate, appear as a more or less connected progressive series of the same great Process." Perhaps we make the unsolved problem of the Origin of Life more difficult than it really is by forgetting that it must have been not merely a biochemical but a biopsychical synthesis.

WHAT ARE THE ESSENTIAL CHARACTERISTICS
OF LIVING CREATURES?

Life is the kind of activity that is characteristic of living creatures. This is another way of saying that life cannot be defined in terms of anything that is not alive. Scientifically and philosophically, this is a tenable position. Life is an activity *sui generis*; for the formulæ of matter and energy (say, electrons, protons, and electro-magnetic radiations or ether-waves) as at present understood do not suffice to describe (*a*) the everyday functions of the body in their orchestration, or (*b*) the activities of any organism at any grade of being, or (*c*) the purposive behaviour of higher animals that are well-endowed with brains, or (*d*) the phenomena of development and heredity, or (*e*) the supreme facts of evolution—which are still in evidence. Every biologist recognizes that the processes and functionings of life are so far analysable into chemical and physical processes; yet these are modified by their occurrence in the colloidal medium of protoplasm. Moreover, when the chemical and physical ledger is added up, it does not give us any unified description of what has actually occurred, let us say, when a migrant bird makes its annual journeys. For to describe these it is necessary to introduce concepts like enregistration of the past, awareness of the present, and purposiveness towards the future. In at least the higher reaches of the Animal Kingdom, behaviour is correlated with psychical activity, incommensurable with physical processes. Thus life is an activity of organisms which requires concepts transcending those of mechanism, chemistry, and physics, helpful though these are.

CHARACTERISTICS OF ORGANISMS.—(A) In a famous passage in his *Crayfish*, Huxley compared the living organism to the whirlpool near Niagara Falls—it is “the constant form of a turmoil of material molecules which are constantly flowing into the animal on the one side and streaming out on the other.” The comparison does not do justice to the characteristic way in which the organism-whirlpool acts on the stream which is its environment, or to the way in which it gives rise to other units like itself, or to the organic regulation of the constant form from within, or to the creature’s mental aspect, but it is a very suggestive comparison. The peculiarity is not that the organism is in continual flux, for chemical change is the rule of the universe; the characteristic feature is that the changes in the organism are so regulated that the integrity of the system is sustained for a longer or shorter period. There is organismal persistence in spite of ceaseless change.

The self-preservative persistence of the organism is associated with the upbuilding and down-breaking of proteins, which have large complex molecules, representing an accumulation of potential chemical energy. Anabolic processes counterbalance the Katabolic; repair counteracts waste; rejuvenescence wards off senescence. The organism is like a clock that winds itself up as it runs down. No doubt this quality is to be analysed as far as may be—in terms, for instance, of the characteristic fermentations and their reversibility. Much depends on the fact that the proteins are always in a colloidal state, which admits of intensity and rapidity of chemical reactions on the surface of the multitudinous ultra-microscopic particles or droplets suspended in the liquid phase. Many features of life are based on the properties of colloids. Another big fact is the chemical individuality that is everywhere manifest, for each distinct type of

organism seems to have some distinctive protein of its own and some characteristic rate or rhythm of metabolism. Thus under the general quality (A) of *persistence amid unceasing metabolism*, there is a triad of facts: (1) the upbuilding that compensates for the down-breaking of proteins, (2) the occurrence of these proteins in a colloidal state, and (3) their specificity from type to type.

(B) The second triad of qualities includes the organism's characteristic powers of *growing, multiplying, and developing*.

GROWTH.—Many biologists have tried to sum up the characteristics of living creatures, and the summations differ very considerably. But all are agreed in giving a prominent place to the power of growth. Living creatures have a fundamental capacity for adding to the amount of their living matter. The egg of a frog is rather under a tenth of an inch in diameter; the frog's body is about four inches long. That means a very considerable increase in the amount of living matter; and while a crystal can grow only at the expense of a solution of the same chemical composition as itself (or of the same crystalline form), a living creature usually grows at the expense of something very different from itself. They say that a single microbe may be represented at the end of twenty-four hours by a progeny requiring thirty figures for its enumeration; and before each of the rapidly succeeding divisions into two there is a short period of rapid growth.

One of the interesting facts that recent work has emphasized is the control that one part of the growing body exerts on another, for growth is a delicately regulated process. Sometimes it runs riot and giants result, but usually it is controlled with some strictness. In the majority of animals there is a very definite limit of growth. In the little flat worms or Planarians that are common in some brooks, the head end, which is the most intensely living

part of the body, exerts a controlling influence on the part of the body behind it. But as the worm grows larger and the posterior part is shoved out to a greater distance from the head end, the controlling influence of the head is correspondingly reduced. Then an interesting self-assertion takes place on the part of the posterior body, which eventuates in its separating off as a new individual. This throws a clear beam of light on various processes of asexual multiplication, whether by dividing into two or by giving off buds. De Beer gives many interesting examples of the regulatedness of growth.

‡ Growth naturally leads to the simplest forms of multiplication or reproduction, for persistent growth tends to bring about organic instability, which may be intracellular, as in unicellular organisms and in ordinary cell-division, or localized along a line of weakness or low vitality, as in the fragmentation of some of the lower multicellular animals. Asexual multiplication is a regularized form of discontinuous growth, and sexual reproduction by means of liberated germ-cells is a secondary specialization, anticipated in the spore-formation of many of the Protozoa and Protophytes.

Development is the progressive attainment of full-grown complexity from comparatively undifferentiated simplicity, whether that be in stump or fragment, leaf or bud, or as spore-cell and germ-cell. It implies an expression of hereditary initiatives in appropriate nurture, and often in such a way that the individual stages in the ontogeny can be correlated with great steps in the racial history or phylogeny. Development, with its central fact of progressive differentiation and integration, is particularly to be thought of in connection with the building up of the embryo, but it cannot be separated from the everyday repair of worn-out tissue, the replacement of periodically deciduous structures (like leaves and hair),

and the frequent regeneration of lost parts. Thus it links back to reproduction and to growth; and there is a connected second triad of qualities characteristic of organisms, namely the capacities for growing, multiplying, and developing.

(C) In the third place living creatures are contrasted with non-living things by their purposive behaviour, by their power of enregistering their experience, and by their capacity for giving rise to the new—a third triad. Many not-living things, such as explosives, react forcefully to outside stimulus, but organisms are marked by the self-preservative efficiency of their reactions. Only the higher big-brained animals can be credited with a perceptual purpose, but the quality of purposiveness seems to many biologists to be coextensive with life. The organism is an agent that gets things done, at various levels of behaviour—intelligent, instinctive, tropistic, reflex, and so forth. The mental aspect may be in many cases subordinated to the bodily, but in the majority there is the bent bow of endeavour, even though the creature's awareness of that endeavour may be dim. The mental aspect seems to be struggling for expression throughout, and to many of its investigators the organism appears as a psychophysical being, now MIND-body and again BODY-mind.

A bar of iron is never quite the same after it has been severely jarred; the fatigue of metals is one of the serious risks of engineering; the violin suffers from mishandling. But these are hardly more than vague analogies of the distinctive power that living creatures have of enregistering the results of their experience, of establishing internal rhythms, of forming conditioned reflexes and habits, and of remembering. Individual experience is built into the individual organism and influences subsequent reactions.

Finally, it must be recognized as characteristic of organisms that they give origin to what is new; they have

evolved in the past, and the evolution of many is still going on. Variability and evolvability must be ranked as fundamental characteristics of living beings. Whatever theory is held in regard to the factors of organic evolution, room must be left for a large fact of life—the bent bow of endeavour. The organism selects stimuli from its environment and often moves from one environment to another; the organism is often experimental, moulding itself by its efforts; the organism tests the newness of its inheritance in its ceaseless trafficking with circumstances. Perhaps the central secret of life is missed if the organism is not recognized as in some measure a struggling sub-personality.

To sum up, the characteristics of organisms are: (A) Persistence of integrity amid ceaseless change, there being (1) a self-preservative compensation of down-breaking by upbuilding, (2) a metabolism of proteins and other complex substances in a colloidal state, and (3) a chemical individuality; (B) a triad of linked capacities, (4) growth, (5) multiplication, and (6) development; and (C) the crowning triad of (7) effective behaviour, (8) enregistration of experience, and (9) evolvability.

ASPECTS OF LIFE.—The biologist works with three co-ordinates—the organism, its functions, and the environment. These are the three sides of the biological prism. At times what is observed is the insurgent Organism acting on its environment, both animate and inanimate; and this may be conveniently summed up by using the first letters, $O \rightarrow f \rightarrow e$, giving the Organism a capital. But at other times, and just as familiarly, the Environment closes in upon the organism, stimulating and inhibiting, fostering and weathering, warming and cooling, feeding and starving, as may be formulated again $E \rightarrow f \rightarrow o$, reversing the capitals in this case. Thus, as Patrick Geddes points out, a useful working definition or descriptive

definition of life is forthcoming. Living implies an ever-changing ratio $\frac{O f e}{E f o}$. Obviously this is not a definition of life, since it includes the term organism, which is just what has to be defined; but it is a convenient and suggestive descriptive definition of living. Thus most animals are less in the grip of their environment than most plants, and sedentary corals more than pelagic medusæ, the very young more than the resiliently mature, and the summer hedgehog more than the hibernator. Since an organism without its everyday functions is rather an empty abstraction, the term function in the $O \rightarrow f \rightarrow e : E \rightarrow f \rightarrow o$ formula should rather read *functionings*, i.e. the work or ongoings, the actions and reactions of the organism as a whole.

THE DRAMA OF LIFE.—What has been said conveys too cold an impression of life, which must be envisaged as a drama on a crowded stage. (1) Whatever the secret of vital activity may be, it must be thought of as an overflowing spring. Organisms accumulate energy acceleratively and must multiply. Life is like a river that is often in flood. (2) From the ant-hill, the bee-hive, the rookery, the rabbit-warren, and the like, there comes the impression of urge and endeavour. Whether the urge be vegetative, appetitive, tropistic, instinctive, or intelligent, organisms are almost always after something—never satisfied. The more they get the more they want. As Joly has put it, “The transfer of energy into any inanimate material system is attended by effects retardative to the transfer and conducive to dissipation.” “The transfer of energy into any animate material system is attended by effects conducive to the transfer and retardative of dissipation.”

(3) But the quality of life rises to what may be called insurgence. Animals in particular are full of daring and

adventure. As Goethe said, they are always attempting the next to the impossible and achieving it. This is well illustrated by gossamer-spiders making aerial journeys or by Arctic Terns within the Antarctic Circle, but it finds many an unsensational expression.

(4) Another quality, so universal that it must be called characteristic, is adaptiveness. Practically every organism is a bundle of adaptations or fitnesses. As Weismann said, if all the adaptations are taken away from a whale, what is there left?

(5) It is perhaps an expression of this adaptiveness that so many living organisms form linkages with others. There is no aloofness in the realm of organisms; nothing lives or dies to itself. Thus Animate Nature is characteristically a system—a fabric that changes in pattern and yet endures. Though the individual threads of the web are always dying, they are replaced without a discontinuity. There is wear, but no tear, except when man carelessly interferes with the loom, or when some physical violence, like flood or fire, causes an inevitable rent.

(6) But this leads to another characteristic of the biosphere that marks it off from the cosmosphere: there is continual sifting. A new star often appears in the sky, but there is no indication of any struggle for existence or selection of the relatively more fit. But who can describe the advancement of life and leave out its winnowing? There is cosmic flux and there is organic flux, but only in the latter is there discriminate elimination. It is characteristic of the *arbor vitæ* that it is always being pruned.

(7) Another characteristic of living creatures is their beauty. All independently living organisms are artistic unities, with protean wealth of beauty in form and colour, in pose and movement, expressing a harmonious

life from which the discordant has been more or less completely eliminated. Apart from exceptions, like parasites, which prove the rule, organisms are like works of art.

(8) Nothing can be said as to the mental aspect of a wood-anemone, and only a little about that of a sea-anemone, but a picture of life must include the fact that in organisms there is the promise and potency—and in higher animals the epiphany—of “Mind.” Perceptual inference is a relatively late achievement; conceptual inference or reason is man’s prerogative; but all through the Animal Kingdom there is, as rill or as river, a stream of inner life, of feeling and purposiveness, even when there is not very much in the way of intelligence. The probability is that “Life” and “Mind” are coextensive, for where can we draw the line? Do not we ourselves arise from a fertilized ovum, carrying our psychic as well as our organic inheritance?

(9) But the crowning characteristic of life is its progressiveness. No doubt there have been eddies and stagnant pools, but on the whole there has been a flow in the stream of life, and it has been uphill! As epoch has succeeded epoch, for inconceivably long ages, life has been slowly creeping—sometimes swiftly leaping—upwards, towards greater fulness and freedom. The whole process must be envisaged in the light of its outcome, organic evolution in the light of Man.

CHAPTER III

WHAT IS PROTOPLASM?

It is a relatively modern idea that we largely consist of a visible something which Huxley called "the physical basis of life," a kind of material with a peculiar activity that we call "living"—a "protoplasm" on whose physical, chemical, and other changes life largely depends. The simplest living creatures are minute specks of protoplasm, which move and feel, grow and multiply, and try to get things done. And our body is built up of thousands of millions of cells or units of living matter, each a microcosm. In the convoluted cortex of our fore-brain there are about 9,200 million cells, about five or six times the number of human beings believed to inhabit the crowded earth to-day. Each of these units consists of a watery mixture of chemical substances which work into one another's hands, and one of the most certain things that we know about this protoplasm is that in our brain its activity is associated with consciousness. No doubt inquiring minds have known for over two millennia that bodily life at least is a flesh-and-blood affair, but even Aristotle did not know what the brain was for, and it was not till about the time of the French Revolution that investigators, such as Lavoisier, began to say to themselves: This life that we know is bound up with chemical and physical changes in a visible material that builds up the body.

If we had an amphitheatre-like museum with four receding galleries, we could arrange a very interesting collection to illustrate biological history and methods. Suppose we also divided each story into quadrants, and kept one quadrant for the study of structure. On the uppermost gallery there would be shown intact forms of

life of all sizes, to illustrate shapes and symmetry. Below that, the next gallery would illustrate organs, which the anatomist discloses with scalpel and forceps, such as heart and lungs, liver and brain. Below that again would come all kinds of tissues, such as muscular and nervous, connective and glandular; and for plants as well as for animals, with slices of wood and bast, pith and rind. Here, of course, there would be many microscopes as well as hand lenses. In the next gallery there would be "cells" of all kinds, animal and vegetable, including egg-cells and sperm-cells and all manner of microbes. These would require better microscopes. Then on the ground-floor there would be the most difficult collection, to show what protoplasm was like. The other quadrants of the amphitheatre museum would illustrate physiology, development, and evolution, but the five levels would be the same—intact organisms, organs, tissues, cells, and protoplasm. Such a museum would help us to realize vividly that our dog, for instance—an embodied mind or an enminded body—is built up of organs, which are fashioned out of tissues, which consist of cells, which are composed of protoplasm and its products.

PURE PROTOPLASM

Living matter is much given to making substances that are not living, so it is not so easy as we might think to get pure protoplasm. When we swallow newly opened oysters or freshly picked strawberries we are dealing with no small amount of living protoplasm, but in both cases it is mixed up with much that is hardly to be included within the charmed circle of life. If we swallow a raw egg we are dealing with very little living matter, for the white of egg consists of a particular kind of albumin, and the yolk of the egg is a protein (vitellin) mixed with a phosphorized fat (lecithin). There is only a minute drop

of pure protoplasm lying on the top of the yolk—the drop out of which a chick might possibly have developed!

There is a quaint living creature of unattractive appearance that is called Flowers of Tan. It creeps about on the bark in the tanyard, and it is rather a pest. On one piece of bark it sometimes covers a patch as big as one's hand, and this is probably the largest splash of fairly pure protoplasm that one can readily obtain. Whether it is a plant or an animal we do not know; it has not made up its mind. Another way of getting fairly pure protoplasm would be to collect a tumblerful of almost yolkless eggs, such as those of a sea-urchin.

There is a general inclination to regard protoplasm as a subtle mixture of proteins, carbohydrates, fats, water, and salts, plus ferments and other subtleties. But it is not a witch's cauldron, it is a chemical firm, perhaps with a sleeping partner called "mind." For it may be that there is no life without a mental aspect. If we put into a test-tube a little white of egg to represent proteins, a little syrup to represent carbohydrates, a little olive oil to represent fats, a little rennet to represent ferments, besides some water and a pinch of salts; and if we shake it up into an emulsion, we have a simulacrum of protoplasm, but it is not, of course, in any sense living. Protoplasm is not a hodge-podge, it is an integrate; and it seems to be *specific* for each kind of creature. For modern investigation deeply confirms the old saying: "All flesh is not the same flesh, for there is one kind of flesh of men, another flesh of beasts, another of fishes, and another of birds." The blood-crystals of a wolf are different from those of its cousin the fox.

In protoplasm there is a fluid medium with seventy-five or more per cent. of water, and in this there are suspended countless particles or unmixing droplets, demonstrable though invisible, often quivering as they are battered by

the adjacently vibrating molecules. In other words, protoplasm is in a colloidal state, and the fundamental fact is that a speck of it presents in proportion to its volume a very large surface on which chemical and physical changes can take place. It may be compared to an archipelago with a very large number of small islands on whose multitudinous coastlines there are endless opportunities for brisk trading. Apart from formed bodies, such as the nucleus, and apart from delicate films which cannot be seen with the ordinary microscope, the protoplasm of a cell is homogeneous and structureless, but it often passes from a "sol" to a "gel" state, setting into a kind of jelly. In most cases it shows a bustle of chemical and physical changes; it is always breaking down and always being built up again; and for long stretches of time it retains its ever-changing integrity. Its symbol is the burning bush, always aflame, yet not consumed. "Nec tamen consumebatur." And in its fiery furnace mind is often at home.

CHAPTER IV

WHAT ARE CHROMOSOMES?

There is always a satisfaction, for the moment at least, in things that we can see; and chromosomes have this advantage over hormones, for instance, that they are visible. Every living creature above the level of the one-celled—that is to say from sponge to man, from seaweed to oak-tree—is built up of cells or modifications of cells. And by a cell is meant a unit corpuscle or area of living matter, usually under the control of a kernel or nucleus. A very small animal, one of the Rotifers or Wheel-Animalcules that can swim through the eye of a needle, has goo-odd cells; and a large animal has many millions.

It is not very useful to think of the cells as comparable to the stones that build up a house, for the fact is that cells are just convenient devices for separating or parcelling out the increasing living matter of the growing organism, so that division of labour becomes more practicable. As De Bary, one of the greatest of botanists, once said: It is not that the cells make the plant; it is rather that the plant makes the cells. As the egg develops into an embryo, and the embryo into a miniature creature, and this into a full-grown adult, there is continual multiplication of cells, and this is not so much like adding brick to brick as like dividing a growing bulk into convenient areas.

Inside each cell, except in unusual cases like mammals' red-blood corpuscles, there is a kernel or nucleus; and there is continual give and take between the living matter inside the nucleus and the living matter outside. The nucleus is bounded by a membrane which is selective in what it allows to pass in and out; and this is a matter of

great importance. But inside the nucleus there is a little world, and prominent in this intricate microcosm are the chromosomes. When the cell is fixed, stained, and cut, the chromosomes often stand out with great distinctness, in many cases like rodlets, sometimes like bent horse-shoes, and for each kind of animal there is a particular number. Ours is forty-eight. There is probably no meaning in the fact that unrelated creatures may have the same number of chromosomes; thus man's number, forty-eight, is also that of certain snails and of one of the varieties of banana. It is difficult to suppose that there is any significance in the fact that the mouse's number is again to be counted in the lily!

But what is important is the constancy with which the specific number of chromosomes is adhered to throughout all the cells of the body. The only departure is in the ripe egg-cells and sperm-cells, which have half the normal number. It follows that at the beginning of each individual life—when the egg-cell is fertilized by the sperm-cell—the normal number is restored. It also follows that when a cell divides into two there must be a longitudinal splitting of each and all of the chromosomes, so that each of the two daughter-cells receives the fit and proper number.

A species is a group of animals or plants which have much in common and breed, on the whole, true. They have an individuality that continues from generation to generation with a high degree of constancy, and they do not usually have fertile offspring when crossed with other kinds. It is very difficult to define a species, but two of the features are distinctiveness and some degree of discontinuity when compared with related kinds. Now, a very interesting recent contribution to this difficult question of species is that related species sometimes form series which differ from one another, not only in the

usual little details, but in the number of their chromosomes. Thus in the genus *Rosa*, which has a great many species, the fundamental number is seven—a very appropriate number for the rose-tree! And it has been found that a series of species of rose can be arranged, which have in their body-cells fourteen, twenty-one, twenty-eight, thirty-five, forty-two, and fifty-six chromosomes—a very interesting result, showing a deep orderliness in diversity. But recent work has gone a step farther by showing that there are five known species of rose with fourteen chromosomes in their body-cells, and that different species with forty-two as their number seem to arise by the combination of three of the species with fourteen as their number. Thus, if the five species with fourteen be represented by a, b, c, d, e, those with forty-two might be represented by a b c, a b d, b c d, c d e, and a d c; and so on.

One of our poets has spoken of sausages as “little bags of mystery,” and the description might serve for chromosomes. They look very solid sometimes, when they are successfully fixed and stained; but in life they are in a semi-fluid colloid state. It seems impossible to refuse to accept the conclusion that they are the bearers or vehicles of many (at least) of the factors that give rise to hereditary qualities. The evidence for this is cumulative: the chromosomes behave so precisely in the ripening and fertilizing of the germ-cells; their behaviour harmonizes with the facts of Mendelian inheritance; the number of chromosomes is sometimes the same as the number of groups of hereditary characters which tend to be linked together in inheritance; the presence or absence of a particular chromosome has been shown in some cases to be associated with a particular quality in the offspring. Thus and thus the argument runs which leads us to regard these microscopically minute “bags of mystery” as the bearers of at least some of the initiatives

which find expression in development in the distinctive qualities of each creature after its kind. We state the conclusion cautiously since we do not wish to rule out the possibility that some of the hereditary qualities may have their seat in the living matter outside the chromosomes.

CHAPTER V

WHAT IS A NERVE IMPULSE?

The physiologist uses the term *irritability* to denote susceptibility to impersonal provocations or stimuli, such as may come from an electric shock, or from a drop of acid on the finger, or from touching a hot cinder, or from a sharp nail puncturing the skin of our big toe. The ending of a sensory nerve is excited, which must mean a sudden disturbance in the living matter; and the consequence of the protoplasmic disturbance is a message, or impulse, or thrill which passes or travels along a nerve to the brain or to the spinal cord at a great velocity of about seventy miles an hour in man's case. This nerve-thrill or nerve impulse is so difficult to understand that it may almost be called an unsolved problem.

Single-celled organisms, such as *Amœbæ*, are susceptible to many kinds of stimuli—changed illumination, changed temperature, chemicals in the water, electric currents, and so on; and it is not surprising that the highly complex living matter or protoplasm should suffer some disturbance—some chemical and physical shock—when exposed to unwonted outside influences. Something is known in regard to the resulting changes in surface-tension, in permeability, in the proportionate number of wandering ions or maimed atoms, and so forth. It follows that there is no special difficulty in understanding that the sensory nerve-ending—which is very much alive and is often markedly amœboid when it is growing—should be profoundly affected by a stimulus from its immediate surroundings. So, but much more simply, is a heap of gunpowder stimulated; but the answer-back is extraordinarily different in the two cases. For the gunpowder

disappears suicidally in its reaction, whereas the nerve-ending is (within wide limits) none the worse, and is soon ready to be excited again. Furthermore, the nerve-ending passes on its excitement in a quick and definite way, so that effective self-preservative action follows.

When we go to be insured the company's physician tells us to sit down and cross our legs at the knee, leaving our right foot dangling. Then with the edge of his hand he strikes (the tendon) just below our right knee, and our foot flies up towards him. This is due to the involuntary contraction of certain muscles on our thigh; but what exactly happens? The mechanical stimulus of the sharp stroke affects sensory nerve-endings below our knee; an impulse travels up sensory nerve-fibres to our spinal cord; a shunting of the message occurs, and a decoding, too, for another impulse immediately comes down certain motor nerve-fibres to certain muscles of our thigh, which obey the "command" to contract. This "knee-jerk" is a typical "reflex action," though there are many simpler ones. It will be noted that the brain is not required for the jerk, though, as a matter of fact, a message *does* travel to our brain; for, even if we have shut our eyes, we wonder, if we are new to the game, what the doctor is after. Our brain may receive the news and we may be aware of it, but the important fact, even for man in whom "mind" is more pervasive than in any beast of the field, is that a nervous impulse must be ranked as a physiological fact, not requiring any postulate of mentality, except indeed in so far as every vital process may imply mentality as well as metabolism.

The pupil of our eye contracts in strong light; our skin reddens after a scratch; these are reflexes which are independent of will or consciousness; and the same must be said of many of the reflexes of the simpler animals, such as starfishes. As a more complex instance, however,

take the familiar experience of our mouth watering at the smell of dinner—a chain that involves (1) the stimulation of sensory cells in our nostril, (2) an ingoing message to the brain, (3) an outgoing message to the salivary glands, and (4) a secretion of salivary juice. But in this particular reflex we must admit that consciousness plays some part, for we *recognize* the savoury smell, and our mouth would not water unless we had enjoyed previous experiences of dinner. If a whistler does not know what a lemon is, he will not be affected in his performance if you bite into the fruit in his presence.

The essential idea of a nervous system becomes plain if we are humble enough to think over a familiar analogy. (1) Scouts (sensory nerve-cells) collect news from the outside world, from friends and enemies, and even from within the camp; (2) the tidings are passed on to headquarters (associative nerve-cells)—where they are decoded, stored, considered, and so forth; (3) the result often is that instructions pass to executive officers, captains, and the like (motor nerve-cells); and (4) they give orders to the men (muscle-cells and gland-cells) who do the work. Groups of nerve-cells or neurons form nerve-centres or ganglia—sensory, associative, and motor—receiving, combining, shunting messages, while the nerve-fibres, which are outgrowths of nerve-cells, remain with the sole function of *transmitting*. The linking together of nerve-cells, especially associative cells, makes it possible to regulate, “unify,” and orchestrate the life of the body and the behaviour of the whole animal; and in the greater groups of associative cells the mind has its home.

A nerve often looks like a translucent whitish piece of twine; it varies greatly in size, from a thread so delicate that we can hardly see it, to the sciatic nerve in our leg (painfully affected in sciatica), which is about half an inch across. Each nerve is wrapped in a glistening sheath

and consists of bundles of nerve-fibres which conduct the messages or impulses. A nerve may include a hundred or hundreds, a thousand or thousands of nerve-fibres, each an independent living thread, which can be distinguished under the microscope, often with a diameter of one-hundredth of a millimetre. Inside each fibre there is a central conducting path or axis cylinder, which continues right into the living matter of a nerve-cell; and this axis cylinder is typically surrounded by a fatty sheath and by an external membrane or neurilemma. Some fibres conduct ingoing impulses from the sense organs or sensory nerve-endings to the nerve-centres in the brain or the nerve-cord; others conduct outgoing impulses from the nerve-centres to the muscles or glands. The two kinds look alike and may lie side by side; but in any one fibre the direction of the message is always either in or out.

When we shut our eye at the approach of a missile we illustrate a very rapid adjustment. Yet it is by no means instantaneous; for an ingoing message has travelled from our retina to our brain, and an outgoing message from our brain to the muscles of the eyelid; and the velocity of these messages can be measured. A common rate in man is 400 feet per second, but this varies with the temperature and also with the size of the nerve-fibre concerned, the thicker fibres carrying the impulse quicker than those still more delicate. In their highly educative *Animal Biology* (1927), Haldane and Huxley point out that "a man, hit by a car going at eighty miles per hour, will probably feel nothing because his brain is destroyed before any nervous impulses from his skin reach it."

The nerve message resembles some other reactions in a peculiarity which is called the "all or none" law. In the case of a heap of gunpowder, a single spark will serve just as well as a blazing torch to bring about the

explosion; and if a stimulus is sufficient to start a nerve message at all, each nerve-fibre affected will carry it at full power. In other words, the impulses that "travel" along any particular kind of healthy nerve-fibre are of constant strength. This may seem at first sight contrary to experience, for do we not feel some stimuli much more acutely than others. But this means that some stimuli affect only a few nerve-endings, while others affect many, or it means that successive stimuli may follow on the heels of one another very rapidly. Experiments have made it certain that all impulses in the same nerve-fibre have the same intensity, but the stimulus must be sufficient to set the impulse a-going.

A weakening of a stretch on the "live wire" (or nerve-fibre), by some anæsthetic for instance, may block the message altogether; but the "all or none" law is illustrated by the remarkable fact that if the message manages to struggle through, it immediately regains all its original power on entering the normal part of the fibre on the far side. It was this kind of behaviour that led Keith Lucas to compare the nerve impulse to the explosion that travels quickly along a train of gunpowder. If the rapidly spreading combustion comes to a damped or broken part of the train, it may be choked off; but, if it manages to get through, it will be as strong as ever on the far side.

This analogy, which must not be pressed too hard, suggests that a nerve-thrill may be something like a rapidly spreading explosion. A living nerve-cell, like any other, uses up oxygen and gives off carbon dioxide; and it has been recently demonstrated, with great difficulty it must be noted, that there is a slight increase in the output of carbon dioxide when an impulse travels along a nerve. Moreover, Professor A. V. Hill and his collaborators have recently succeeded in showing, by means of an ingenious apparatus of great sensitiveness, that there is

a definite production of heat by a nerve-fibre in the transmission of an impulse. Of course, the quantity of heat produced is very small—enough in a second to raise the temperature of the “live wire” by one ten-thousandth part of a degree. But it is interesting to find that this quantity of heat corresponds closely with the formation of the minute quantity of carbon dioxide which was demonstrated by Professor G. H. Parker.

It is easy to send a message along a nerve by electrically stimulating the end, as when we receive a mild shock from a battery, or even touch the electric fish called the Torpedo. It is also well known that electric currents (“currents of action”) appear when a message passes along a nerve; and it is probable that electric forces are of primary importance in the *starting* of every nerve-impulse and in its *shunting* from one nerve-fibre to another. But there can be no question of calling the impulse as a whole an electrical current, for the production of a little carbon dioxide and heat points to chemical activity in the living matter of the nerve.

The nature of a nerve impulse—one of the most familiar phenomena of life—remains an unsolved problem; but we know something more about it every year, and it will certainly become less and less of a puzzle even if physiologists are forced in the long run to appeal to some irreducible property of life—such as “irritability.”

CHAPTER VI

WHY DO WE FALL ASLEEP?

This is a very difficult question, and none of the answers that have been suggested can be said to command general assent. It is not difficult to point out the utility of sleep, for living implies a running-down of the clock, and sleep is a time for winding it up. Sleep affords opportunity to accumulate savings for another bout of energetic spending. As Professor Halliburton says in his well-known *Handbook of Physiology*, which has passed through sixteen editions or more, "sleep is the period of anabolism, repair, and growth. Loss of sleep is more damaging than starvation."

But the need for rest and repair does not explain how it is that we become sleepy. Moreover, our spinal cord never goes to sleep, and the medulla oblongata of the brain is never more than a little somnolent; so why should the higher parts of the nervous system require a rest that the other parts do not demand? Moreover, the hard-worked heart never stops—except momentarily—till it can no more; and our breathing movements continue in our deepest slumbers, sometimes with vibrations of the soft palate that are obtrusively obvious to others though all but unperceived by ourselves. If the heart can go on beating for threescore years and ten, why should our cerebral hemispheres, which we rarely work so hard, demand a long rest every twenty-four hours? And, again, for the great majority of animals sleep is quite unknown, and many never even condescend to take a rest.

There are some animals that pass into a state of inertness when they are lifted off the ground, and this has been attributed to the sudden shutting off of the current

of impressions that normally serve to keep the creatures active. So some unhealthy people fall into a sleep-like state whenever they shut their eyes, thus excluding the news that usually kept them awake.

If we disconnect our bodily telephone by shutting our eyes and by closing the shutters of our room there are few external calls to keep us awake, though there may be sleep-banishing disturbances within the bodily house itself. It is safe to say that one of the conditions of sleep is a diminution in the number of afferent impulses that usually force their way into our central nervous system.

Another factor is habit; and that is bound up, in a great part of the globe, with the regular alternation of day and night. From infancy onwards the habit of sleeping has grown on us, and the organism is readily amenable to the establishment of rhythms. The more methodical our habits of going to bed, the more likely are we to sleep soundly.

This sometimes becomes curiously complicated by the establishment of "conditioned reflexes" or associations. That is to say, certain stimuli, such as a lullaby for a child, a nightcap for a man, become inextricably linked with the habit of falling asleep; and they may often assist in enforcing the rhythm when external conditions are not propitious. It is well known that many working men sleep soundly all day and work hard all night. Darkness is not necessary, though it is a useful abettor of sleep. Are there not many nocturnal animals?

Many of us say to ourselves that we fall asleep because we are tired; and this is one of the favourite theories of sleep—a biochemical theory. For being tired probably means that certain specific toxins or poisons are formed by particular forms of hard work, by nervous activity in particular, and these toxins accumulate in the blood until they begin to inhibit or paralyse the higher nerve-

centres associated with consciousness. There is not, indeed, so far as we can see, any absolute necessity for this; for the body is continually masking and filtering out the poisonous waste-products which it manufactures, and why should it not do the same more rapidly for the sleep-producing toxins which are assumed to disappear in our slumbers, especially during the first two hours? But it may be sufficient to answer that the periodic enforcement of rest is for various reasons so very useful that a slow way of dealing with certain nerve-toxins has been tolerated.

One of the arguments in favour of the hypothesis of sleep-producing fatigue-toxins is the experiment of injecting into a fresh animal some of the blood of another that is falling asleep with extreme over-exertion. The injection is said to be immediately followed by deep sleep.

There is no doubt that the wheels of the sleeping body are not going round so quickly as in waking hours; yet digestion goes on, breathing-movements do not cease, the beating of the heart continues, the filtering of the blood proceeds, the muscles, fortunately, do not cease to produce heat, and they remain in a state of gentle tension or tonus. In intermediate physiological states, where some of the higher motor-centres of the brain do not fall asleep, there is the possibility of moving about—to wit, somnambulism. After a period of lowered brain circulation, associated with tiredness and much reduced reactivity, there is in the first hour or two of refreshing slumber an increase in the flow of blood to the brain; and this probably implies a sluicing out of inhibiting toxins.

But the central fact about sleep is the relative interruption of the ordinarily continuous consciousness. This is what separates sleep so markedly from a profound rest.

Apart from dreams, which are mostly very rapid, we spend about a third of our life in a state of unconsciousness.

No doubt many of the lower animals take long rests, like the queen humble-bee throughout the winter; but this rest is far away from what we know as sleep; and the same must be said of hibernation. This brings us to the hypothesis that sleep is an inhibition of mental activity, or of the higher brain-centres, by a particular nerve-toxin, which is chiefly produced in the more intelligent animals. So far as we know, a relatively stupid mammal like a guinea-pig never falls asleep. But sleep conquers the highly evolved intelligence of the dog and the horse; and both of them dream!

Difficult cases will no doubt occur to the reader; but we submit the thesis that sleep is a tax on intelligence—a reaction to a specific neuro-toxin, which is eliminated during the psycho-physical rest. Thus (reversing an old adage), we say: Eight hours' sleep for many a man, seven for many a woman, and six for any everyday fool. The proof of our theory is manifold, but one piece of evidence is our present desire for slumber.

CHAPTER VII

WHAT IS SUSPENDED ANIMATION?

In a fascinating book, *Hunting Under the Microscope*, the late Sir Arthur Shipley, one of the most distinguished of British zoologists, discussed among other subjects the problem of "suspended animation." Everyone knows the puzzle of the latent life of seeds in the seedsman's shop. They show no sign of livingness; they do not require oxygen or water; and yet they are alive, else they would not be saleable. They are more inert than frozen streams.

There are a great many ways of "lying low" which cannot as yet be arranged in scientific order. There is an almost complete cessation of livingness due to extreme drought, or to extreme cold, or to lack of oxygen; but there are many other states, like cold coma, winter lethargy, heat torpor, where livingness is still demonstrable.

The comatose, lethargic, torpid organism, such as the queen humble-bee in winter, is like a sleeping fire, banked up in its own ashes—not exactly burning, yet not out. Quite by themselves are the hibernators among mammals, such as hedgehog and dormouse, which are imperfectly warm-blooded, and which can relapse into a very peculiar but life-saving physiological condition, not very happily called "winter sleep." In many ways the living creature comes extraordinarily near the gates of death, and yet does not die.

A simple animal, like a paste-eel, may survive drought so thorough that the body becomes brittle; a cataleptic insect may be held out rigidly by one of its unmoving legs; a frog may survive being frozen stiff in its winter retreat.

How can we tell when they have crossed the bourne from which there is no return?

The question becomes still more difficult when we take account of local life and local death, cases where part of the body begins to decay though the creature still lives, or where a part remains active though the creature may be dead. The heart of a turtle may still beat, though the rest of the animal has been made into soup. It is said that a seed or a germ or an entire organism must be counted living so long as it gives a certain, rather delicate, electrical reaction. Surer, perhaps, is the fact that when the protein molecules of an essential organ have begun to undergo wholesale disintegration, the organism is on the other side of the gates.

What interests us particularly in Shipley's essay on *Suspended Animation* is his open-minded discussion of man's possibilities in the way of defying death. If an African mudfish can lie low for seven months of the year, why should man be dogmatic about his powers over his body? If a hedgehog can survive a prolonged hibernation in which the heart beats very slowly and feebly, the breathing movements are scarce perceptible, and the function of renal excretion has quite stopped, why should not man have greater powers of lying low than he is yet aware of?

Whatever be the relation of Mind to Body, the mental aspect has emancipated itself from the trammels of protoplasm to a greater degree in man than in any other creature; and it is interesting to inquire whether man might not have more power over his body than he is in the habit of exerting.

We do not suppose that there is much practical advantage in a dying man rallying his forces to live another day at the gates of death; but the inquiry is theoretically interesting; and it might possibly lead to some advance

in the art of sleeping and resting, in which some people greatly excel others.

There are many records of men and women passing into a prolonged involuntary trance; but in these cases there is usually a distinctly pathological factor. More interesting, though little studied, are the deliberately induced trances of Indian fakirs.

There are some striking instances in Verworn's *General Physiology*, quoted from James Braid, who discovered hypnotism. Thus Runjeet Singh's fakir was sewn up in a sack, which was deposited in a locked box in a sealed room in the palace, where he remained for six weeks. He was not very lively when things were opened up—including his teeth with a knife—but he was soon able to ask Runjeet Singh—"Do you believe me now?"

Some of the fakirs have been exposed as fakers, but there is a pleasant open-mindedness in what Verworn says :

From the standpoint of an unprejudiced science we must say that it would be an entire mistake superciliously to regard a thing as untrue merely because at first sight the reports appear strange, and because an impostor employs it for purposes of gain. . . . If from all the known stories their more or less sensational accompaniments be removed, the simple statement remains that certain men can voluntarily put themselves into a state in which no vital phenomena are demonstrable by a more or less superficial examination, and can awaken later to normal life.

We cannot cite as scientific evidence the memorable story of the *Master of Ballantrae* who was buried for over a week without actually dying; but there was the well-known case of Colonel Townsend, described by Dr. Cheyne of Dublin. He was an engaging man who "could die or expire when he pleased, and yet, by an effort or somehow, he could come alive again." What is wanted, however, by us all, is *increased* not suspended animation; our point is simply that we might be helped to the former by a scientific study of the latter.

CHAPTER VIII

WHAT IS MEANT BY FEIGNING DEATH?

If an infuriated cobra be deftly seized behind the head and subjected to a little mild constraint, it becomes as stiff as a stick. It has passed into the state technically known as animal hypnosis or catalepsy—a state that has been known for a very long time, for the sticks which the magicians long ago threw down before Pharaoh and turned into snakes were no doubt snakes which had been previously turned into sticks. Most naturalists prefer to experiment with a type less exciting than a cobra, and the little freshwater crayfish serves excellently. If you place it head downwards on the table and, without hurting it, prevent it from moving, it soon gives up the struggle—though not so soon as many other animals—and becomes quite stiff upside down, or on its back, or leaning at an angle of forty-five degrees propped up by its forceps, or anyhow, if it is in equilibrium. As you hold it, before the catalepsy sets in, you know that the muscles are being stimulated to contract and that you are constraining them to disobedience. It is strange to feel them passing into a state of rigor. Many fisher-boys know that a similar state can be readily induced in the shore-crab, or in the edible crab, if they grip it between finger and thumb by the dorsal shield and wave it twice or thrice in the air. A very interesting detail is that the female crab bends her forceps and walking legs inwards and upwards upon the tail, as if to protect the eggs which are sometimes attached there, while the male disposes his otherwise.

A mathematician and Orientalist of the seventeenth century, Daniel Schweitzer, gets credit for being the first

to describe the familiar experiment of "how to make a quite wild hen so tame that it will sit quietly by itself without moving and in great fear." This was how he phrased the problem in his *Deliciæ Physicomathematicæ* (1636). But the "experimentum mirabile de imaginatione gallinæ" is oftenest associated with Father Athanasius Kircher, who told (in 1646) how he bound a hen's feet, laid in on the floor and drew a chalk line in front of its eyes, with the result that it remained for a long time as if paralysed. It is now well known that this experiment can be made with many different kinds of birds, and that it is not the least necessary to tie the feet or to draw a chalk line. The famous French entomologist, Fabre, confessed that he and his schoolmates used to catch the neighbours' turkeys, put the head beneath the wing, and wave them up and down till they fell asleep, after which they could be aggravatingly disposed in absurd situations.

The same sort of thing may be done with rabbits, guinea-pigs, mice, squirrels, bats, and even with cats and dogs—the usual method being to fix them, without doing them any harm, to a board, and then turn this quickly upside down. Cats and dogs pass readily from the hypnotic state into true sleep, from which, however, they can be instantaneously awakened by blowing on them or by some sudden noise. All zoologists know how easily, and sometimes unexpectedly, frogs pass into hypnosis, sometimes simply when they are held between one's two hands. If the limbs are bent into quaint positions at the outset of their immobility, they will remain cataleptically in the given pose. Toads and newts have also been known to submit, and we have already referred to snakes. A quaint case is that of the Californian horned lizard or *Phrynosoma*—the creature which sends a jet of blood from its upper eyelid when it is much excited. If one of these fascinating animals be gently stroked on the top of its

head, it closes its eyes and passes into stupor for five or ten minutes. Naturalists have discussed whether this is a faint or a feint, but in all probability it is hypnosis. Perhaps the most remarkable fact in regard to the hypnotic state among backboned animals is simply its high degree of uselessness. Apart from a few cases of mammals "playing 'possum"—witness the Australian dingo, and of ground birds squatting motionless when hotly pursued—cases which require more careful observation than has ever been given to them—we do not know that the capacity for hypnosis is of any real service. It is a laboratory phenomenon, and it looks as if it were just an enigmatical concomitant of a specialized nervous system which has been tolerated by natural selection, partly, perhaps, because it remains for all practical purposes latent. It is possible, however, that in natural conditions of wild life crises occur more frequently than we suppose, when the best policy is Brer Rabbit's—lying low and saying nothing, especially in the face of quite unusual and bewildering situations.

When we pass to backboneless animals the difficulty lessens, though it does not disappear. Many insects and crustaceans "feign death," and this seems often to have protective value. The cataleptic escapes the danger of being pecked at. Many animals that will bite at moving booty will not or cannot attack the motionless. The protectiveness reaches a climax in some of the stick-insects, which feed at night and are motionless during the day. In form and colour they resemble twigs, and when the sunlight pulls the trigger of their dormativeness, they arrange their feelers and limbs in a line with their stick-like body and remain fixed parallel to the branch, or at an acute angle with it. The assumption of the fittest pose is very interesting, for it suggests that the creature has some dim awareness of its line of safety.

When the stick-insect is molested in spite of its garment of invisibility it lets go its hold and sinks through the meshwork of leaves and twigs, and it has been plausibly suggested that the elongated disposition of the limbs makes it easier for the creature to sink down and escape detection.

In some stick-insects, which look like slender, dry twigs, a great part of the adult life is spent in a state of quiescence. For hours—it may be for a whole day—the insect will remain absolutely still, without stirring a leg or a feeler. After a long rest the creature suddenly begins to rock itself quickly on its legs. The insect can be given any pose by bending the legs gently; one stood on its head for over four hours. The muscles are taut, but they are not set, as in lockjaw; they are in a state of half-contraction. Moreover, the insect is unresponsive to what is done to it, though persistent pinching of its tail will make it wake up. Dr. P. Schmidt once rested the feelers and front legs of the stick-insect on a book, and the tail on another book. The middle of the living bridge was weighted by strips of paper, but the insect did not stir.

What is the cause of this strange state? We know this much—that it depends on a brain-disturbance which affects the whole nervous system, reducing sensitiveness, removing the power of response, and causing a peculiar condition of the muscles of the whole body. But it is not known what brings about the brain-disturbance, except that the stick-insect can bring it about itself. Dr. Schmidt found that the creatures entered into the state more readily when left alone, showing that the causes are internal, so he called it auto-catalepsy. Perhaps it is a resting state, something like sleep, but going farther into cessation of activity; and this may have become a racial habit because of its useful purpose. For the resting stick-insect could not by the slightest movement betray its

presence when disturbed. It approaches the state of the hen and the snake, but its rigidity is of regular and normal occurrence.

There is a common sandhopper that burrows near high-tide mark. If you lift it gently and lay it on the palm of your hand, it lies quiet and immobile in a state like that of animal hypnosis. After a few minutes it slowly straightens itself and then suddenly jerks its body with great force. It was there and—it is gone! Now, Professor S. J. Holmes has observed that other kinds of sandhoppers show this habit of lying low in a less marked way, less and less the more aquatic they are, till, finally, we find some thoroughly aquatic kinds which do not do more than stop dead when they come up against a solid surface like a rock.

This is very interesting, for it suggests that the habit may be the outcome of successive improvements on the habit of stopping dead when something new is touched.

Now, if all the cases were like that of the stick-insects, we could at once understand why the capacity for hypnosis should be widespread, but in numerous cases the difficulty alluded to returns, that no utility can be suggested. Thus Fabre refers to one of the ground beetles, *Scarites buparius*, which a shake sends into a prolonged immobility. It is a large beetle, strongly armoured, with formidable jaws, nocturnal in its habits, and unpalatable—just the sort of creature, in fact, that has no need whatever of playing 'possum. It has a smaller relative, *Scarites lavigatus*, which is much more in need of protection, but its hypnosis lasts for only a few seconds, and the interesting point is that when it is molested it pulls itself together and makes off. Two or three cases are known where the capacity for hypnosis has actually come to be of service in connection with pairing, and it may be

that we should recognize its utility more frequently if we knew more about the detailed habits of animals. At present we must be content with saying that it is a puzzling capacity which has only here and there been brought into the direct service of the organism.

In a recent work which marks a distinct step, Professor E. Mangold seeks to show that the typical forms of animal hypnosis must be ranked along with human hypnosis, there being only one marked difference, that hypnosis is induced in man by a psychical inhibition and in animals by mechanical inhibition. It may also be noted that animal hypnosis does not go so far as man's. In both cases the occurrence may be assisted by some unusual sensory stimulus (visual, tactile, or other), or by some sudden change in the stimulation, but this is by no means essential. True hypnosis in man and animals implies a sleep-like state, an inhibition of locomotion, an inability to "right" the body when put into some abnormal pose, a marked change in the muscular tonus (sometimes extreme limpness and flexibility, sometimes cataleptic rigor, sometimes both), and a decrease in sensitiveness to touch and to pain (operations may be performed during hypnosis). In both cases the rapidity of the passage into and out of the hypnosis is sometimes very striking. In both the awakening may be spontaneous, or it may be effected by something relatively trivial, such as a puff of air or a whistle. A very interesting point, which gives one something to meditate over, is this: When the hypnosis in man is not very deep, the patient is in some measure aware of what is going on, for he remembers about it afterwards. Similarly, it has been observed that if some grains of corn be dropped down in front of the eyes of a hen in the hypnotic state she sometimes tries to peck at them, and may awaken in an attempt to swallow. It seems, therefore, that as she lies there, as if

paralysed, she has some mentality available—enough to remember what grains of corn are good for!

Many physiologists have contributed to our understanding of this mysterious state of animal hypnosis—we think especially of the researches of Czermak and Verworn—but a stride forwards is due to the work of Professor E. Mangold, who has shown that human hypnosis cannot be separated off from animal hypnosis, nor the phenomena of playing 'possum, feigning death, and catalepsy from those of experimentally induced hypnosis. Mangold proposes a useful classification, which helps us to see the related facts in a series. First, there is experimental hypnosis physically induced by suggestion—in man and perhaps in some of the highest animals such as horses. Second, there is experimental hypnosis mechanically induced—in many birds and mammals, in snakes, lizards, and amphibians, in crayfishes, and some insects. Third, there is natural hypnosis induced by environmental stimuli, as in the death-feigning and catalepsy of some insects. To this very important setting of things in order we wish to add the suggestion that the initial stage in the whole series may be a phenomenon exhibited by many of the lower animals of stopping abruptly when there is a sudden change in the routine of their sensory stimulation. The swimmers in a dark aquarium come suddenly on a beam of light, and they stop as if struck dead. You put your hand between the sun and the expanded tentacles of a tubicolous worm, and there is instantaneous retraction. Perhaps this widespread and, on the whole, very profitable reaction of signalling "Dead slow" when the stimulation is perplexing may be at the root of animal hypnosis.

Three general reflections rise in the mind. First, that the demonstration of this hypnotic capacity in many organisms in which it was unsuspected shows that we

should be chary of supposing that we have sounded the depths of organismal and especially neural possibilities. Second, that it is very interesting to observe how a capacity is retained for ages so long as it is not in the way; retained, as it were, on the off-chance of its being of use. There is a magnificent conservatism in evolution. Third, that progress is being made in bringing into line a whole series of states, the scientific marshalling of which will be great gain—the stoppage often associated with differential sensitiveness, the paralysis of fear, cold coma, suspended animation, trance, catalepsy, animal hypnosis, human hypnosis, sleep, hibernation, and latent life.

Here is the beginning of an attempt. Some simple animals seem to be disturbed when they pass suddenly from darkness to light, or from water to dry ground, or when they touch something strange to them. They stop short; activity is switched off. This has become an engrained answer-back, and it is a useful one. When one's world is topsy-turvy it is better to keep quiet. This engrained answer-back might be a starting-point for the sandhopper's lying low; it might reappear in accentuated form in animal hypnosis; it might be regularized and made part of a resting habit in insect catalepsy; it might reappear in a higher guise in fear-paralysis; and in a really clever creature like a fox the habit might form the foundation of a genuine trick.

Perhaps we should then make a fresh start with fatigue. Exertion means burning fuel on the hearth of life, oxygen is used up, ashes gather. How natural, then, is rest! How likely, moreover, it is that regular alternations of work and rest should be established, especially in relation to day and night, to summer and winter! But there is shallow rest and there is the deep rest of sleep. Perhaps sleep is partly due to fatigue; partly to lack of oxygen—as yawning suggests, for a yawn is an attempt to get

more air; partly to a tired heart which is not sending enough blood to the brain; and partly to the shutting out of the stream of intruding messages which keep us awake. But these are only the immediate causes of an old-established constitutional rhythm. Now, along with sleep, regarded as a special case of fatigue-rest, we may put the fatal coma of animals overtaken by a snowstorm, or the sleepiness of animals whose liver and kidneys are not removing poisons. And so we pass quite gradually to the long winter sleep which often draws so near to the confines of natural death. One step more brings us to latent life, or suspended animation, in which creatures may survive for years without showing any sign of vitality. The last step is the death of the body.

CHAPTER IX

ARE ANIMALS EVER AFRAID?

There are naturalists who declare that animals have no fear, and they are probably right in believing that even the higher animals do not suffer, as we do, from any clear apprehension of disaster or from any foreboding of death. But no one who has seen a pigeon about to be crushed by a python, or a rabbit soon to be caught by a stoat, can doubt that there is in some animals something analogous to fear, though not to foreboding.

The emotion is, perhaps, confined to birds and mammals; it is part of the higher forms of the instinct of self-preservation, and we fancy that it always implies some anticipation of impending *pain*. We once saw a young antelope in a South African paddock being cruelly punished by an insulted senior, and as it rushed about, dripping with blood, seeking escape, there was fear writ large in its eyes. No doubt each of these creatures has its own fear, but fear there is.

A generation ago, when motor-cars were unfamiliar in out-of-the-way parts of the country, we saw in one day two curious sights. It was in the west of Ross-shire, where a friend had taken us in his new touring-car. As we rose over the crest of a hill, with that bound of a powerful car which always seems suggestive of a big bird taking wing, we saw on a roadside far ahead an old wife with a creel of peats. She saw us too—this fearful engine gliding so swiftly and silently down the slope—and she laid down her creel and ran to the shelter of a peat-stack, where she hid.

Perhaps she feared the sight of this strange thing; perhaps she wished to conceal herself and her dress from

foreign eyes; more probably, however, she was just taken aback by an unexpected apparition, and yielded to the natural impulse to take to one's heels. If so, what we saw was a human example of a very common occurrence in animal life. Something unexpected, unknown, or menacing is seen or heard; this pulls the trigger of the emotion of fear; and this sets the motor-engines of the body at work, "full steam ahead, or astern," a chain of sequences forged in the course of ages, and made secure because it is so profitable.

A very self-controlled physician, with a good stock of presence of mind, told us that when a shell fell not very far from him in the course of a London raid he had difficulty in resisting a very strong impulse to run away. An unusual experience pulled the trigger of an ancient impulse to run from the approach of a danger that could not be faced or fought. It is likely that the strong emotion also affected the secretion of some gland—probably the supra-renal gland, which sends chemical messengers of commanding power through the body by means of the blood. Part of the weariness after bombing is said to have been due to the hard task that the supra-renal glands had in responding to the strong emotional excitement. We must be careful lest we go beyond what is proved, but it seems very likely that the stirring-up of chemical messengers distributed by the blood when a creature is in danger may help that creature to run away effectively.

On the day we saw the old woman run and hide we witnessed the very opposite. We came suddenly upon a Highland pony, slouching half asleep in the middle of the road. It heard and saw us all too suddenly, for it became quite stiff and rigid. We did not know before how true the phrase *petrified with fear* may be. Two of us got out of the car to lead the pony aside, but we could

not make it move. There was no question of obstinacy; the creature's legs were as if it had died and stiffened, and in the end we had to lift the pony off the road as if it were a hobby-horse.

What happened in this case was a sort of temporary paralysis, such as is sometimes caused in birds by a sudden shot, or in a rabbit when it looks round and sees the stoat close upon it. The experience is so violent that the nervous arrangements are thrown out of gear. The heart may stop, so that the brain does not get its proper supply of blood. Thus a quite uninjured bird may fall to the ground, a startled seal may allow itself to be captured. Sometimes there is no need to assume any emotional storm of fear; the suddenness of a startling experience may be enough to paralyse a creature, and to throw its bodily machine out of gear. A faint may be brought about by an emotional shock—a piece of bad news; it may also be brought about by a purely physiological shock, such as falling into very cold water.

But there are cases among higher animals where fear must, we think, be recognized as a genuine factor. Thus a dog was once frightened into a sort of fit by a bone drawn across the floor on an invisible thread, and it has been said that any man's heart would stop beating if he saw his chair moving *by itself* across the floor.

The facts are by no means clear, but it looks as if fear-paralysis, a little like what is sometimes called hysterical paralysis, was so useful in the case of certain animals that it became in time a hereditary device. We call it a device, but it is very unlikely that the death-feint—the lying low in an immovable state—is ever at such a high level of conscious purpose as the behaviour of a clever mammal like an otter when it hides itself. On the other hand, the feigning of death by, say, an opossum is not at such a low level as the fear-paralysis

of the rabbit, which is unusual and quite abnormal. It is perhaps between these two levels.

One difference between the opossum feigning death and the Highland pony paralysed by fear is that in the first case the muscles are not rigid, while in the second case they are almost as stiff as if the creature had lockjaw. We think the best cases of death-feigning in birds and mammals are midway between fear-paralysis and the intense inactivity of, say, a brooding bird. Intelligent advantage is taken of a natural power, and the creature is appreciatively aware of the situation.

Mr. W. H. Hudson, the well-known naturalist, tells of the death-feigning of the fox of Argentina, which lies stretched out, with its eyes shut, quite unresponsive. Even the dogs seem to regard it as dead. "But when one withdraws a little way from the feigning fox and watches him very attentively (says Mr. Hudson), a slight opening of the eye may be detected; and, finally, when left to himself, he does not recover and start up like an animal that has been stunned, but slowly and cautiously raises his head first, and gets up only when his foes are at a safe distance." Our interpretation would be that, while many animals in extreme distress—especially the rabbit that looks round and sees the stoat all too near—will become paralysed with fear, it is open to still cleverer creatures to utilize the reawakening process with great efficiency, or even to feign the emotion of fear by a sort of auto-suggestion. Activity in such creatures may be switched off by pain, by fear of pain, and by will.

CHAPTER X

WHAT ARE HORMONES?

A gland is an organ or a patch of tissue that manufactures an organic substance at the expense of its living matter and gets rid of it as a secretion. Thus the pancreas or sweetbread produces three digestive ferments and gets rid of them by the pancreatic duct or ducts, by which they enter the food-canal, there to digest the food. But there are some glands that have no ducts, and cannot get rid of their secretion except into the blood-vessels which form a network through and through them. Such glands are called ductless, or technically endocrinal, and they are the sources of the remarkable substances called hormones which are distributed by the blood throughout the body.

Hormones were discovered by Professors Bayliss and Starling in 1902, and the discovery has greatly changed our view of the internal life of the body. For the hormones, also called "chemical messengers," serve to regulate and harmonize the internal activities so that they work into one another's hands, as if they had, in St. Paul's words, "a common concern for one another." The word "hormone" means a stirrer-up, something that excites or provokes; but some of them act in the opposite way in soothing-down or quieting. As yet they are hardly known except in backboneed animals, but two or three cases among backboneless animals lead us to expect further discoveries in that field. That they play an important part in plant life is almost certain, one of the best established cases being that of the Sensitive Plant, where they apparently serve to carry a stimulus from one leaf to another.

When a cat, taken by surprise, turns to face a meddlesome dog, it arches up its body and its sleek fur rises on end. The dog is often taken aback by the cat's sudden attitude of resistance, by the tense muscles, and by the fierce look in the eyes, so that it often finds it convenient to become profoundly interested in something else. Several naturalists of half a century ago went the length of saying that the cat deliberately made itself bigger in the eyes of the dog by willing its fur to stand on end, but we now know that what happens is very different from willing or taking thought. The cat has an emotional storm, largely we fancy of the nature of anger, and the influence of this spreads through the body by the nerves, and a particular ductless gland, called the supra-renal body, situated in front of the kidney, is stimulated to increased activity.

There is an extra production of a hormone called adrenalin, which is made by the central portion of the supra-renal body and is distributed by the blood throughout the body. It serves to increase the "tone" of the muscles, the "pressure" of the blood, the amount of sugar in the blood, the clotting power of the blood, and so on. One of its far-off effects is to stimulate the tiny muscles that raise the hairs. So the cat's fur stands on end, and its whole body is ready for a fight which is often unnecessary. One of the many interesting facts in regard to adrenalin is that it can now be made artificially in the chemical laboratory. It is sold in the druggists' shops, and used to stop nose-bleeding and the like, for making the blood clot is one of its many potent properties. What is true for the cat holds for an angry man, that his body by anger and by adrenalin may be prepared for a fight—a preparation that works both for good and for ill.

Another important hormone is that produced by the thyroid gland, which lies on each side of our voice-box

or larynx. If it is deficient in activity at the proper time, the growing child suffers arrest of development in body and mind, but may be happily cured by utilizing extracts of the thyroid gland of sheep or calf. The thyroid hormone, which is absolutely necessary for our continued health, is called thyroxin, and, like adrenalin, it can now be built up artificially by the chemist—a step of great practical importance.

Very important hormones are made by a small body, called the pituitary, which lies on the under surface of the brain in backboneed animals. This organ, about the size of a hazel-nut in man, makes several hormones, one of which regulates growth and keeps a child from becoming an unhealthy dwarf or an unhealthy giant. An interesting point is that the frog's frequent change of colour is due to a pituitary messenger carried by the blood to the pigment-cells of the skin. Similarly it is under the influence of a hormone from its reproductive organs that a male frog develops its swollen first finger at the breeding season; and the same may be said of the stag with his annual growth of antlers.

This is a large subject, but perhaps we have said enough to suggest how these hormones have a very important rôle in binding the living body into a unity, so that one part thrills to another in a remarkable way. Without hormones, in backboneed animals, there would be no harmony.

CHAPTER XI

WHY DO WE LAUGH?

There is something almost laughable in the number of theories about laughter. Still more in the way they contradict one another. Freud regards laughter as a means of effecting "economy of psychic expenditure," but Boris Sidis maintains that we laugh in the overflowing abundance of our joy. Professor William MacDougall regards laughter as a safeguard against the fatigue and depression of our tendency to show too much sympathy. This is a modernizing of Byron's view:

And if I laugh at any mortal thing
It is that I may not weep;

but it stands in contrast to the long-lived theory of Hobbes, that we laugh because we are lacking in sympathy and have a "sudden glory" in discovering "some eminency in ourselves by comparison with the infirmities of others."

The reason for the contradictoriness which these instances merely illustrate is not far to seek. It is due to preoccupation with the subtler and more sophisticated forms of laughter, instead of beginning with the more primitive. Moreover, there has often been a mixing up of three inquiries:

- (1) What is the essential nature of primitive laughter?
- (2) What has given laughter survival value? and
- (3) What are the main stimuli of laughter?

It was Darwin, as usual, who first got down to bed-rock by recognizing laughter as an inborn predisposition, approximated to in monkeys and some other animals,

finding simple expression in children, and excitable by a variety of stimuli which may be far away from the ludicrous. On the physiological side, he said, laughter involves: (1) a deep inspiration followed by short, interrupted, spasmodic contractions of the chest and diaphragm; (2) opening of the mouth, drawing the corners backwards and a little upwards, raising the upper lip and showing the teeth; (3) movements of the head, quivering of the lower jaw, contraction of the orbicular muscles; and (4) the reiteration of the characteristic laughing sounds, which vary notably in their quality in different people. Herbert Spencer also disclosed something of the physiological aspect of laughter, pointing out, for instance, the value of diffused movements in relieving the surplus energy of mental excitement.

We wish to suggest a supplementary biological theory of laughter which seems to have much in its favour and to be necessary to cover the facts. The characteristic feature of primitive laughter, such as is induced by tickling, is a momentary loss of control over vocalization, facial musculature, and respiratory movements. A sudden stimulus, of which tickling is the crudest, inhibits the normal automatic controls, and we have to laugh. A pathological expression is hysterical laughter, which has been observed in dogs. Our theory is that laughter is primarily a localized relaxation of control under the stimulus of strong emotion, sudden surprise—especially if agreeable (yet not always)—an unexpected failure, an incongruity, and the like. It is quite possible that the liberation of some hormone is concerned in this abatement, or even sweeping away, of the usual controls and inhibitions. Often the loss of control gathers momentum, so to speak, and people laugh till they cry, or even suffer considerable pain.

Our personal theory of laughter has to do only with

its primary nature. It requires to be immediately added that modern civilized laughter does not necessarily imply any lack of control, for the predisposition to laughter—to what Leigh Hunt well called a “happy convulsion”—has been regularized, humanized, moralized, and socialized. It has come to have very interesting secondary justifications. Thus Bergson has laid emphasis on the social importance of laughter, as when we laugh the clumsy and the cranky out of court. “By laughter, society avenges itself for the liberties taken with it.” It is a social discipline.

A famous explorer and archæologist has told us that in a critical situation he always looked out for the native with humour in his eye, and tried by some conciliatory joke to make him laugh, which often solved the problem. Laughter is a social lubricant. This theory has been elaborated by Gopalaswami, who thinks that laughter has evolved out of man’s defence group of impulses. Laughter is often a shield. More than that, it may disarm opposition and make the enemy relax. Many a fight has been obviated by a timely joke. Not that this is thought out as a policy; it is nearer the instinctive and traditional.

Among the secondary justifications of laughter a place must also be found, we think, for MacDougall’s subtle theory that it is sometimes “the antidote to sympathy.” In laughter some highly evolved people relieve themselves from the sympathetic pain involved in contemplating some maladjustment or disharmony. These examples must serve to illustrate the secondary justifications that have given regularized laughter survival value.

The third question has to do with the diverse stimuli that make people laugh. Here Dr. Kimmins, writing from a rich experience, has much that is interesting to say in regard to the provocatives to laughter in children. The frequent reproach, “I don’t see anything to laugh

at in that," may be salutary, but it does not suggest an understanding of the situation. In simple cases the surprise, the incongruity, the bursting bubble, the sitting down on a hat, and so forth provoke laughter as irresistibly as tickling does. Sully laid emphasis on the novelty of the unexpected; Spencer stressed what he called somewhat ponderously "descending incongruity" when a given situation on the large scale is suddenly replaced by one on a very small scale—the mountain giving birth to a mouse; Hazlitt spoke of a disturbance of the expected sequence of events or even words "taking the mind unawares." Bergson, always original, maintains that we laugh when we see a living creature, a human being in particular, behaving like a machine. "We laugh every time a person gives us the impression of being a thing." The Custom-house officers who had helped to rescue the passengers from a wreck near Dieppe could not keep from asking them "If they had anything to declare"; and laughter could not but mingle with tears.

While Sully regarded laughter as a grown-up smile, which is in a sense true for the individual, Darwin was perhaps deeper in his suggestion that the adult smile is the outcome of laughter-control. In all likelihood our descendants will laugh less than we do, and smile more. At present many people smile much too loudly.

CHAPTER XII

WHY DO WE CRY?

There is a very quaint desert lizard in Mexico and California that goes by the name of Horned Toad or Phrynosome. It is a non-aggressive creature, asking only to be left alone, but it becomes greatly excited when it is teased. It is said to shed tears of blood, and this is in a remarkable way the case. When it is much perturbed there is a rush of blood to the head, and the eyelids become so much congested that they swell to twice or thrice their ordinary size, and from below the upper one there issues a fine jet of blood! There is a superficial hæmorrhage, occurring under very unusual circumstances, and it is such an expensive mode of weeping that we cannot wonder at its being unique. It corresponds in part to a man's eyes becoming bloodshot in a rage, and it throws from a distance some light on weeping.

Just as with laughter, so in regard to tears, we must not think first of the sophisticated human reason. For a number of mammals shed tears copiously, and the primary reason must be relatively simple.

In Darwin's *Expression of the Emotions*—a book far too little read—some facts are given in regard to the weeping of some monkeys and the Indian elephant; and other cases are known, without including "crocodiles' tears," which seem to have been exaggerated.

It is a familiar experience that a flow of tears may follow a strong scent, a blow, irritant particles in the eye, exposure to intense cold, and in short a great variety of stimuli. What happens is an exaggeration of the normal secretion of the lachrymal gland, whose normal function is to moisten the surface of the eye (the conjunctiva).

Our tears issue from several ducts on the inner surface of the upper eyelid, and some of them are caught by a small aperture in the lower lid and pass through the lachrymal sac into the nasal passage. The others, as we are all aware, overflow and roll down our cheeks.

The exaggerated secretion may clear the eyes, which is always advantageous, even if you wish to give a kiss for a blow, and the tears may also have their utility in the nostril, e.g. in increasing olfactory sensitiveness. And apart from utility the exaggerated secretion comes as a relief to changes in the blood-pressure and musculature in the region of the eye and its glands. We must recall the Phrynosome "weeping blood."

It is not unusual to see strong men weeping copiously at a comedy, even in response to stimuli so different as Sir Harry Lauder and Professor Leacock. We have seen people laugh till the tears rolled down their cheeks, and there is something almost sacred in tears of joy.

Very young children cry vocally long before they shed a tear, and Darwin found that a frequent age for the first true weeping was about three months.

The flow of tears in early childhood may express pain and distress, but it is often worked towards by a fit of screaming that expresses vexation at some thwarted wish. Later on, the weeping is gradually inhibited until it is only evoked by very deep emotion. In many cases the muscular contractions associated with profuse weeping in children may be seen in strongly emotionalized adults although the supply of tears has long since ceased.

Although Darwin credited some mammals, like monkeys and elephants, with a capacity for copious tears, he thought this was absent in the anthropoid apes, and this is borne out by recent observations. In his striking book on the *Mentality of Apes*, Professor Köhler distinctly says that he never saw one weep. Their expressions of

grief are undoubted, but these are not associated with tears. The fact that weeping seems to require some practice in young children is in harmony with Darwin's conclusion that the habit "must have been acquired since the period when man branched off from the common progenitor of the genus *Homo* and of the non-weeping anthropomorphous apes."

Some races weep much more readily than others, as may be noticed among sailors and soldiers under very severe exposure, but this is an intricate question. The more emotionalized types will tend to weep more readily, but this may be entirely counteracted by habituated control.

According to Darwin, the origin of weeping in the individual child is to be found in the gorging of the blood-vessels of the eye as the result of prolonged screaming, this being due to pain or hunger or the like. The gorging of the blood-vessels of the eye is associated with a contraction of the surrounding muscles and with other effects which react reflexly on the lachrymal glands and induce exaggerated secretion of tears.

On this view, crying is primary and weeping is a secondary consequence. It is not of great physiological use, perhaps, for it is not without justification that we speak of "idle tears"; and yet it has been racially justified as a safety-valve which lessens congestion and may actually relieve pain. In all probability, however, the biology of tears requires another chapter, which will disclose the influence of some hormone, such as adrenalin, which has such a notable influence on the tone of the muscles, the blood-pressure, the breathing movements, and so forth. It is well known that an extra supply of adrenalin follows an emotional storm, like that of anger. The sympathetic nervous system is excited; the thrill passes to the suprarenal bodies; more adrenalin is produced and rapidly

distributed throughout the body by the blood stream. As already noted, the cat's hair stands on end automatically in an emotional gust induced by an obtrusive dog: so it may be that our tears have a similar emotional-endocrinal factor.

CHAPTER XIII

WHAT IS THE MEANING OF COLOUR?

In the parapet of the fine staircase in the Oxford Examination Hall there is a piece of Labradorite with a bewitching blue colour that recalls the tail of a peacock and the wing of a *Morpho* butterfly. It is interesting to notice how it rivets the attention of visitors—this little bit of colour amid the stateliness and beauty of architectural form. Why is it that this changeful splash warms so many hearts, even more than the poetic tower of Magdalen? What is the magic of colour?

Blessed be the man, said Sancho Panza, who invented sleep. Blessed be the organisms, we say, who invented colour. A colourless world would not be uninteresting; but it would be very difficult and dull. Some may say that one cannot even imagine a living world without green leaves and red blood; but we are not sure. The red seaweeds have chlorophyll whose green colour is quite disguised, and there are many animals with oxygen-capturing pigments hidden in their practically transparent blood. Everyone is glad, however, that he lives in a world of blue sky, purple heather, green trees, marigolds or poppies in the corn, robin redbreasts, and yellowhammers in the hedge.

The colour of a body depends on its filtering of or interference with visible white light. When rays of a certain wave-length, from violet to red, are removed, the balance of the white light is disturbed, and we see the "complementary" colour. Thus light that passes through a very thin sheet of copper appears as green because the red rays have been absorbed. Yet the same copper in a polished disc will appear to be red, for the red rays are those that

are chiefly reflected from its surface. Whiteness means a very perfect reflection of the whole of the light, and the reflecting surfaces, as in white hairs, white feathers, white flowers, white snow, and white foam, are often due to bubbles or vacuoles of air entangled among the particles. The colour may be entirely a question of *physical structure*, depending, for instance, on the fine grating of the surface, or on the reflection from two surfaces at different levels. Thus a soap-bubble has exuberant colour though it is made of transparent soapy water, and mother-of-pearl has many of the colours of the rainbow though it becomes white chalk when pounded to powder. There is no pigment in the blue sky or in the blue sea.

But the commonest cause of colour may be said to be *chemical* rather than physical. This is a distinction that is wearing rather thin, but in many plants and animals there are substances, called pigments, whose molecules have the property of absorbing or of reflecting only certain parts of the visible spectrum. Thus the hæmoglobin of our blood, the chlorophyll-complex in green leaves, the zoonerythrin of a prawn, the anthocyan of the rosy-cheeked apple, and the melanin of a negro's skin may be mentioned as pigments. Why certain chemical properties should be associated with certain colours is a difficult question.

But the finest of all colours are due to *combinations of pigmentary and structural* factors. That is to say, the colour due to the chemical properties of the molecules of the substance is enhanced or modified by minute superficial gratings or fine platelets or other peculiarities of architecture. Thus there is no blue pigment in the peacock's tail or in the gorgeous wing of the Morpho butterfly. To sum up, there is purely structural colour, without any pigment, as in mother-of-pearl; there is purely pigmentary colour without any enhancement due to minute

architecture, as in black hair or red blood, though differences will arise with varying quantities; and, thirdly, there is a combination of structural and pigmentary coloration, as in a humming-bird or a Red Admiral butterfly.

All this is necessary to a right understanding of the significance of pigments. For, in the first place, there are some pigments that have a high physiological importance, though this does not depend on their colour as such. Thus there seem to be four pigments grouped together in the chlorophyll of the green leaf, and these are the most important pigments in the world, since they enable the green plant to utilize some of the energy of the sunlight in building up carbon compounds (photosynthesis). But their importance does not essentially depend on their appearing green, as the masked red seaweeds prove.

The red blood-pigment, hæmoglobin, is in some ways like chlorophyll, but its importance is in serving as an oxygen-capturer and oxygen-carrier. It consists of a coloured portion called hæm and a colourless protein portion called globin; and it has analogues like hæmocyannin (in many backboneless animals), which also function in respiration, though not quite so effectively.

Also concerned with oxygen is a recently discovered and widely distributed pigment called cytochrome, occurring inconspicuously in many, if not all, animals and plants. It was discovered in 1925 by Keilin, and it is perhaps too soon to appreciate its importance with security. But chlorophyll, hæmoglobin, and cytochrome may be cited as foremost illustrations of pigments that play an essential part in the business of life.

In the second place there are pigments which are derived from more essential substances, or are by-products of the chemical routine (metabolism) of the body. Thus

there is the green pigment (biliverdin) of the bile, which may also occur in the tissues of lower animals, and seems to be produced by the breaking-down of hæmoglobin. So we suggest a second group for pigments that are not important in themselves but are wrapped up with what is essential. They form part of the material that may be secondarily utilized for protective or advertising purposes.

Let us take another good example. All living matter contains the nitrogenous carbon compounds familiarly known as proteins, and the normal food of most animals must include proteins. As the result of the breaking-down of proteins there is a production of amino-acids, and a very widely distributed amino-acid is tyrosine. Now if some pure tyrosine is treated in a test-tube with a ferment called tyrosinase (also of wide occurrence in animals), and exposed to air, the result is first a reddish and then a dark substance that is practically identical with the black pigment (melanin) of many dark-coloured animals. In this (or in another equally natural) way dark pigments may be formed; and Przibram has shown that the colour produced in the test-tube varies greatly according to the conditions of exposure. The same diversity may well occur in the living body, and be secondarily utilized for concealment, or for adornment, or for protection from the glare of the sun. These dark pigments or melanins occur in hair and feathers and skin, in the black choroid layer that makes a dark chamber in the eye, in the ink of the cuttle-fish, in the lining of the body-cavity in many fishes and reptiles. The point is that the first question should always be in regard to the physiological significance or derivation of the pigment, and second, into its natural-history utility, if it has any.

Another important group of pigments may be illustrated by the two yellow substances, carotin and xanthophyll,

that accompany the two greens of chlorophyll proper. They belong to the group of "chromolipoids" or "lipochromes," "coloured fat-like bodies." They occur in ruddy feathers and orange-red fishes, in yellow fat and yellow yolk, in the shells of many crustaceans, and in a great diversity of animals. Their chief origin seems to be from the food, and their ultimate source is the green plant. Here again we have a natural starting-point for what may be afterwards utilized for some subsidiary purpose. We might go on to speak of other kinds of pigments, such as the anthocyanins of many flowers, the uric-acid pigments of yellow butterflies, indigo and its animal counterpart in Tyrian purple, and so on; but our object here is to suggest that a physiological consideration of pigments (and a not less difficult study of the fine details of minute structure, such as the ripple marks of growth) should precede the secondary inquiry, to which we shall now turn, into the various *uses of colour* as such. Pigments first, and then colours.

A kingfisher flying upstream like an arrow made of a piece of rainbow; the golden oranges amidst their glossy leaves; the newly caught herring, blue and green, silvery and red; the bluebells ringing by the wayside; the ripe cherries gleaming like cornelians; the purple heather on the moor; the poppies ablaze among the corn; the rubies and emeralds of the Bird of Paradise; the golden king-cups in the ditch; the deep scarlet of the Poor-Man's Weather-Glass; the azure of the Arion butterfly's wing; the subtle iridescence of the worn shells wetted by the incoming tide; the daring display of the parrot; the elusive browns of the brooding woodcock—what does it all mean, this long gamut of coloration? A joy for ever, of course; but this narrow human point of view, though by no means unreasonable, is not satisfying.

In certain cases a dark colour may protect the animal

from the glare of the sun, and this utility would not be in the least inconsistent with the discovery of a physiological reason for the deposition of an extra quantity of melanin in the skin.

For a warm-blooded creature in very cold surroundings the dress that conserves most of the precious animal heat is a dress of white fur or white feathers, as in ermine and ptarmigan, but this is not inconsistent with the discovery of a physiological reason for the development of gas-vacuoles and the non-formation of pigment in the suit of fur or feathers that is put on when winter comes. Nor is it inconsistent with proving that the whiteness is of protective value in making the ermine or the ptarmigan inconspicuous against a background of snow.

Protective or cryptic coloration is certainly very common, but its life-saving value should be proved, not simply assumed. Not every case is so satisfactorily documented as that of the green Praying Mantis on the green herbage, and the brown variety among the withered leaves. For in this case the protective value has been proved up to the hilt and statistically measured, which is certainly not true of the white winter dress of the mountain-hare among the snow. The value of colour in supplying a cloak of invisibility is increased when the markings are also like those of the surroundings, as in the brooding woodcock, or when there are possibilities of colour-adjustment, as in the flat-fish among the gravel. The climax is reached in cases of true mimicry, as when a palatable butterfly gains safety by being the "double" of an unpalatable species with which it consorts.

Somewhat difficult are many of the cases of alleged "warning colours," where an unpalatable animal is very conspicuous, like a yellow-and-black salamander or a red-and-green Burnet Moth. The theory is that the conspicuousness serves as a *noli-me-tangere* advertisement, impressing

itself on the memory of a forgetful enemy; saying to him, as it were, This gaily coloured creature is of no use, leave it alone. Of some such warning colours there is considerable experimental evidence.

On a firmer footing are the numerous cases where the bright colouring of the male animal contributes to the ensemble that interests or excites his desired mate. Among the bower-birds there seems to be a delight in brightly coloured objects, such as shells and pods, for their own sake—the dawning of an æsthetic sense.

Sometimes the colours serve as advertisements of palatability, as in some insect-attracting flowers or bird-attracting fruits, but here again, in many cases, there is need for replacing surmise by precise demonstration. Thus, without denying that colour may have some attractive value to hive-bees, we are sure that the fragrance of the flowers is not less important.

The mention of flowers recalls another use of colour, what may be called a way-post function. As Sprengel indicated long before Darwin, there are often conspicuous spots on the petals of flowers which certainly look as if they might be of use in guiding the insect-visitors to the nectar. It is not necessary to suppose that the insects would not find their way without the “honey-guides,” but anything that prevents fumbling will tend to have survival value. The whitewashed stones by the footpath are not indispensable to the belated traveller, but they enable him to walk more rapidly and confidently.

Many nestlings have very bright colours inside their mouth; and Pycraft has pointed out that the conspicuousness of these, when the young birds gape, may enable the parents to supply the food with greater rapidity and precision. This may seem a trivial matter, but survival in the struggle for existence often depends on small differences, like that between *Shibboleth* and *Sibboleth*.

We need not continue our illustrations of the uses of colour among living creatures, but we reiterate the two points: that the first inquiry should refer to the primary significance of the pigment or the architecture on which the coloration depends, and that the secondary significance of the coloration, if it has any, should be, as far as possible, demonstrated. In many cases, we venture to think, the colour has no use at all, unless we count as a use the delight it gives to human eyes.

CHAPTER XIV

IN HOW MANY DIFFERENT WAYS MAY ANIMALS APPEAR GREEN?

If an ordinary citizen who has not thought of such things be suddenly asked how he knows a plant from an animal—the tree from the squirrel, so to speak—he may probably answer first of all that plants are fixed, whereas animals are free. This is a good commonsense distinction; but it is blunted not a little when we show him sponges, corals, zoophytes, sea-fans, sea-lilies, sea-mats, barnacles, oysters, mussels, sea-squirts, and so forth. For all these are genuine animals; and yet fixed after the early chapters of their life are past.

And if our ordinary citizen goes on to say that plants are green, while animals are not, he is again emphasizing a commonsense distinction, yet one that cannot be sustained as a hard-and-fast rule. For he remembers mushrooms and toadstools, which are genuine plants; though without any of the characteristic plant-pigment, or complex of four pigments, called chlorophyll. Moreover, everyone knows that many seaweeds are red and brown, so that although they have chlorophyll, only the botanist can swear to its presence. But the colour-distinction breaks down badly on the other side, for there are many animals that are green. It is to these that we now wish to give attention, and the inquiry has a peculiar interest since there are actually five different ways in which animals may appear green.

The genealogical tree of living creatures is like a letter V: the extremes of its two main stems, such as tree and squirrel, are very far apart, but the differences lessen among the simpler forms of plants and animals till they

are lost in Protists, primitive forms of life which have not taken a decisive step in either direction.

(1) It is not unnatural, therefore, that there should be a few animals that have the characteristic plant-pigments that are summed up in the term chlorophyll. Thus the green colour sometimes seen in the water of stagnant pools is frequently due to a minute flagellate animal (for most zoologists claim it as such) called *Euglena viridis*, which has chlorophyll corpuscles like those of plants. Similarly, if the beautiful Volvox, a revolving ball of a thousand or ten thousand cells, is an animal, then it is another that has gained possession of chlorophyll. There is also a green Bell-Animalcule, *Vorticella viridis*, which seems to have chlorophyll belonging to itself. The advantage is great, for the chlorophyll enables the animal to feed like a plant—on carbonic acid gas.

(2) But the number of animals that have chlorophyll in their own right, so to speak, is small. A much commoner cause of green colour is that the animal has entered into intimate internal partnership with one-celled algæ which have chlorophyll. So it is in the green trumpet-shaped Infusorian called Stentor, in the green freshwater sponge, in the green species of freshwater Hydra, in many green sea-anemones, and in the little green Convoluta worm of sandy beaches at Roscoff in Brittany. Some of the corals and their near relatives on the reefs are vividly green, and in many cases this is due to a great multitude of greenish one-celled algæ (*Zoochlorella* by name) living in the inner layer cells of the polyps. Here, then, the green colour is not due to the animal itself, but to its symbions or partner-plants, on whose synthetized food-products, such as sugars, it in part depends.

The chlorophyll of plants, which usually has its seat in very minute corpuscles like penny buns in shape, is a complex of four pigments, two of which, the chlorophylls

proper, have mainly to do with the all-important capturing of part of the energy of the red-orange rays, and the utilization of this to reduce carbonic acid and build up formaldehyde or some simple sugar. We cannot enter here on any discussion of the chemical composition of chlorophyll, but it is extraordinarily interesting to notice that it has a deep resemblance to the red pigment (hæmoglobin) of the blood in backboned animals, and in some backboneless animals as well.

(3) The next point that we wish to make clear is that there are a few animals with green pigments entirely different from chlorophyll. A very good instance is the pigment called bonellein, which gives a beautiful green colour to the highly interesting Mediterranean worm called *Bonellia viridis*. This bonellein is a green pigment, but it does not seem to have anything to do with chlorophyll, either chemically or physiologically. The same may be said of a green pigment (turacoverdin) in the feathers of two or three Plantain-Eaters, and of the bile-pigment (biliverdin) found in the shells of some sea-snails. There are some green marine worms that have a pigment called chlorocruorin that has, like our red blood-pigment, a power of capturing oxygen, and is thus of respiratory significance to its possessors.

(4) Not a few insects have a bright green colour, as we see in green grasshoppers, green cockroaches, and green beetles. This colouring has not been much studied, but we know that in many cases there is no green pigment present. There may be a brownish or other coloured pigment, but the green colour is a purely physical effect, due to the fine structure of the insect's cuticle on which the light falls. In the same way there is no green or blue pigment in the peacock's tail or in a gaudy parrot's plumage. Pigment there is, but it is not green; the green appearance and the metallic enhancement of the total

effect is due to the fine texture of the feather-surface.

We are not dealing here with hidden green substances, such as the green pigments (biliverdin) of the bile, or the beautiful green vivianite in the bones of the Gar-fish or *Belone*.

(5) But as to external appearance there is still another kind of green animal—namely, the green tree-sloth of the Brazilian forests. The green colour of this paradoxical creature is actually due to the presence of one-celled algæ, which flourish on the outer surface of the moist and shaggy hairs. So there are at least five different kinds of green animal.

CHAPTER XV

WHAT IS SEX?

The males and females of many animals are so different that they have been called by different names: stag and hind, cock and hen, ruff and reeve, drake and duck. Sometimes zoologists have been misguided enough to put the male and female into different species.

If we turn from highly evolved creatures like the peacock and peahen to, let us say, sea-urchins, we cannot tell male from female without using a microscope, unless, indeed, we have looked at so many that we can distinguish the texture of the egg-producing organs or ovaries from that of the sperm-producing organs or testes. The sexes of sea-urchins are to the eye practically identical, yet the fundamental difference is there; the one is an egg-producer and the other a sperm-producer.

If we knew what this difference means physiologically or biochemically, we should have discovered the still hidden secret of sex. As yet we do not know the true inwardness of the difference between maleness and femaleness. Even if we could arrange matters so that of two young *Bonellias* one developed into a big female and the other into a pigmy male, as one of the investigators declares that he can do, we should not thereby have quite discovered what is the deep difference between the sexes. It is probably some contrast in the fundamental chemical routine or metabolism of the creature, some alternative that sways the body to one side or the other, and sometimes not quite decisively to either.

The theory that maleness and femaleness depend on some difference in the physiological "gearing" or chemical routine is suggested by interesting cases where the sex

changes in the course of the lifetime. Thus, according to Dr. J. T. Cunningham, and Nansen also, who was a zoologist before he became an explorer, there is a normal change of sex in the curious deep-water hagfish, *Myxine glutinosa*. Those that are about a foot in length are females; the smaller ones are males. The testis is gradually replaced by an ovary. In an interesting starfish, called *Asterina gibbosa*, many individuals are first male and then female; others are hermaphrodite (male and female in one); others seem to be permanent males or permanent females. This case should be looked into afresh. Another strange case is that of a worm called *Grubea protandrica*, which is male in autumn and winter, female in spring, and neuter in summer! These instances of normal sex change are not to be mixed up with others where something abnormal, such as a disease or a parasite, brings about the sex-reversal. Thus when something goes wrong with the ovary of a duck, the bird may put on the drake's plumage at the next moult.

Some kinds of crabs are attacked by crustacean parasites related distantly to barnacles. These parasites destroy the reproductive organs of the male crab, which proceeds to put on some feminine characteristics and even to produce eggs. The narrow tucked-up tail of the male crab broadens till it is about half-way towards the female's broad tail, and some egg-carrying abdominal limbs may develop. The full-grown parasite protrudes like a haricot bean under the crab's tail, and absorbs nutritive fluid by means of root-like threads which penetrate through its host's body.

But the quaintest of all the changes induced on the male crab is that he defends his protruding parasite as a female does her bunch of eggs. If the victim be a female, there is no change of structure or of instinct except that she cherishes the parasite instead of eggs—which cease to

be formed. It seems probable that the parasite alters the composition of the male's blood to or towards the female condition, and that this, along with the actual castration, induces the development of female and feminine characteristics. This seems to support what may be called the physiological view of sex, that femaleness means a relative preponderance of up-building, constructive, or anabolic processes, and maleness the reverse.

Every country boy knows that the male bees or drones do not sting. The reason is that the sting is a transformed egg-laying organ or ovipositor, and must therefore be restricted to the females or queens, and to the workers, which are arrested females. Now there are many such cases of sex-dimorphism, where one can see a good reason for the difference between male and female. The male frog has a swollen first finger, which is used in embracing; it is, of course, unswollen in the female, and we know that the swelling begins when a hormone or chemical messenger from the lusty male frog's reproductive organs is distributed through the body by the blood. But there are scores of cases where the utility of the secondary sex-characters is not very obvious, and where we are inclined to think that they simply express the momentum or the exaggeration of two different constitutions. No one can tell with certainty what is the use of the enormous six-foot tusk of the male narwhal, represented in the female by a rudiment. It is usual to say that the antlers of stags are for fighting with, but they are far from being effective weapons. In the Reindeer they are present in both sexes; in the Water Deer they are absent from both.

Many of the differences between males and females may be interpreted as weapons useful in the combats of rival males, or as decorations and other attractive features, useful in rousing the interest and the excitement of the

females. But it seems to us that there are many others in regard to which we can only say that they are expressions of deep constitutional differences between the sexes, and that they have sometimes come to be so closely linked to the hormones liberated from the reproductive organs that their development or non-development depends on these.

We have admitted that we do not yet know what the essence of maleness and femaleness is; but we have followed Geddes in regarding it as a subtle biochemical quality, some difference in what might be called the physiological gearing. According to this theory, for which there is much to be said, the sexes differ in the rate and rhythm of their metabolic processes. Since the chemical routine of the body consists of two sets of processes, up-building and down-breaking, winding up and running down, anabolism and katabolism, it may be that the ratio of the former to the latter is always greater in the female. In other words, the relatively more constructive or anabolic constitution spells female; the relatively more disruptive or katabolic constitution spells male.

On this view it is not difficult to understand how it is that an animal that changes its constitution very markedly in the course of its lifetime should also change its sex. Thus all the smaller hagfishes, or Myxines, are males, but as they grow larger they turn into females. The little starfish, *Asterina gibbosa*, may be male, female, or both, according to age and circumstances.

Country folk have been for a long time familiar with hens that took to crowing, and worse, or with ducks that put on drake's plumage; and many similarly puzzling phenomena are well known. The modern interpretation is that a degeneration of the ovary implies a suppression of the ovarian chemical messenger or hormone which

keeps the latent masculine characters from finding expression. In other cases it is possible that the ovary normally removes from the blood some substance that would allow of the development of masculine characters. Similarly, it is known in many cases that hormones from the male are indispensable if the superficial masculine characters are to develop, such as the antlers of stags or combs and wattles and plumage decorations in cock-birds. The discovery of the sex-hormones has thrown light on numerous minor puzzles of sex, though enough is not yet known to explain how these invisible elixirs are able to exert such a potent influence.

As in other cells, there is in the egg-cell and in the sperm-cell a nucleus with a definite number of readily stainable bodies or chromosomes. In many cases, e.g. mammals, half of the spermatozoa have a special sex-chromosome and half have not. If an egg containing a sex-chromosome be fertilized by a sperm with a sex-chromosome, the result will be a female; while if an egg with a sex-chromosome be fertilized by a sperm without a sex-chromosome the result will be a male. This is a common state of affairs, but there are other possibilities which also depend on the presence or absence of a sex-chromosome. Thus, in birds the sperms are all alike, but there are two sorts of egg-cells, with and without sex-chromosomes.

The chromosomes, though fluid in their natural condition, can be made very definite and substantial by fixing and staining the cells, and there are good reasons for believing that they are the carriers or vehicles of many, at least, of the hereditary characters. And a very interesting conclusion is that the sex-chromosome carries what are known as sex-linked characters. Thus, in mankind, the characters of night-blindness (an inability to see in faint light) and hæmophilia (a tendency to

females. But it seems to us that there are many others in regard to which we can only say that they are expressions of deep constitutional differences between the sexes, and that they have sometimes come to be so closely linked to the hormones liberated from the reproductive organs that their development or non-development depends on these.

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Country folk have been for a long time familiar with hens that took to crowing, and worse, or with ducks that put on drake's plumage; and many similarly puzzling phenomena are well known. The modern interpretation is that a degeneration of the ovary implies a suppression of the ovarian chemical messenger or hormone which

keeps the latent masculine characters from finding expression. In other cases it is possible that the ovary normally removes from the blood some substance that would allow of the development of masculine characters. Similarly, it is known in many cases that hormones from the male are indispensable if the superficial masculine characters are to develop, such as the antlers of stags or combs and wattles and plumage decorations in cock-birds. The discovery of the sex-hormones has thrown light on numerous minor puzzles of sex, though enough is not yet known to explain how these invisible elixirs are able to exert such a potent influence.

As in other cells, there is in the egg-cell and in the sperm-cell a nucleus with a definite number of readily stainable bodies or chromosomes. In many cases, e.g. mammals, half of the spermatozoa have a special sex-chromosome and half have not. If an egg containing a sex-chromosome be fertilized by a sperm with a sex-chromosome, the result will be a female; while if an egg with a sex-chromosome be fertilized by a sperm without a sex-chromosome the result will be a male. This is a common state of affairs, but there are other possibilities which also depend on the presence or absence of a sex-chromosome. Thus, in birds the sperms are all alike, but there are two sorts of egg-cells, with and without sex-chromosomes.

The chromosomes, though fluid in their natural condition, can be made very definite and substantial by fixing and staining the cells, and there are good reasons for believing that they are the carriers or vehicles of many, at least, of the hereditary characters. And a very interesting conclusion is that the sex-chromosome carries what are known as sex-linked characters. Thus, in mankind, the characters of night-blindness (an inability to see in faint light) and hæmophilia (a tendency to

bleed dangerously from slight wounds) are confined to males. The factors for these two characters are carried by the sex-chromosome, and this throws light on analogous puzzling facts, e.g. on the much greater frequency of colour-blindness among men than among women.

CHAPTER XVI

WHAT SETTLES SEX?

The philanthropic fowl laid an egg yesterday and it may develop into a cock; it lays another egg to-day and it may develop into a hen. What makes the difference? Out of a thousand eggs liberated in the pond by a female frog and fertilized by a male frog, 570 will develop into females and 430 into males, unless, of course, they are eaten up before they reach maturity. What makes the difference?

There have been scores of answers to this question, and the probability is that the answers should be many, not one. What determines sex in a frog may not apply in the case of a fowl; what is true for a worm may not be relevant for man. Announcing his new theory, an enthusiast declared that it superseded 262, which were erroneous; and to this a critic immediately replied that nothing was more certain than that the new theory was the 263rd, which it was necessary to reject.

IS THE BIAS DUE TO NURTURE?

In some animals, like frogs, sex is slow of declaring itself; and it has often been suggested that during the early stages of development the bias may be given towards maleness or towards femaleness by differences in nutrition and environment. When Yung fed his tadpoles on the minced flesh of ox, fish, and frog, he got the respective percentages of females, 78, 81, and 92.

But the snag here is that the experimenter did not take account of the deaths. This is a fatal fallacy, for there might be differential mortality. It is necessary to discover, for instance, whether the males are not more

susceptible than the females to any departure from the normal nurture.

In the worm *Bonellia*, already mentioned, the free-swimming stages look all alike, but those that settle down in the mud develop into large females, while those that fix themselves to the proboscis of a full-grown female and begin to absorb the skin-secretion are arrested and develop into the dwarf parasitic males. This looks like sex-determination by nurture. In most cases, however, the sex of the offspring seems to be determined by the time the egg is fertilized.

There are certain facts which point to the theory, favoured by many breeders, that decision may depend on the relative ripeness of the egg-cells and sperm-cells at the time of fertilization. Thus Kuschakewitsch found that out of a large number of over-ripe frogs' eggs, whose fertilization had been artificially delayed, all the survivors developed into females.

TWO KINDS OF GERM-CELLS

Some animals have two visibly different kinds of eggs. Thus in the common Wheel-Animalcule *Hydatina* and in the vine-pest *Phylloxera* there are large ova which always develop into females and small ones which always develop into males, no fertilization being required in either case. Similarly, in the mite *Pediculopsis*, and in a primitive worm called *Dinophilus*, where fertilization occurs as usual, there are large eggs which develop into females and small eggs which develop into males. An interesting point has been noticed in regard to "identical twins"—developing from one egg-cell—that they are invariably of the same sex, which may or may not be the case when the twins arise, as is usually the case, from two separate egg-cells developing simultaneously.

In one of the armadillos there are normally "identical

quadruplets," which are always of the same sex. In some of the strange parasitic Hymenoptera, such as Encyrtus, a single egg-cell develops into a group of embryos, all of the same sex, but with this peculiarity, that all are female if the egg is fertilized and male if not. Everyone knows that drone bees develop from unfertilized eggs. Drones have a mother, but no father; yet they have a grandfather!

SELECTION OF EGG-CELLS

There is considerable evidence that the ovary of a pigeon produces two kinds of eggs, differing in their yolk-forming capacity and in other features; and that those predisposed to more abundant assimilation and storage will develop into females. Now, it is probably impossible to change the bias of an egg predisposed to developing into a female or of another predisposed to developing into a male. But it is possible that the diet and the habits of the parent bird may affect the proportion of the two kinds of ova produced in the ovary. Thus a prolonged dieting with very nutritious food might result in a disproportionate number of female-producing ova. It is well known that green flies produce females only during the abundance and prosperity of the summer months, but suddenly produce males when autumn sets in with its cold and short commons. Experiments in prolonged dieting of mammals have not disclosed any influence on the proportion of the sexes.

IS SEX A MENDELIAN CHARACTER?

Many biologists believe that sex behaves as a Mendelian character. Thus, in the common Currant Moth there is strong evidence that the females are "heterozygous," that is to say they have "maleness" as a latent or recessive character. They will, on this view, give rise to equal

contingents of male-producing and female-producing ova. The male moths, on the other hand, are "homozygous" as regards sex, being without the "femaleness factor"; and, on this view, they will give rise to only male-producing spermatozoa. When a male-producing spermatozoon fertilizes a male-producing ovum, the result is, of course, a male. But if a male-producing spermatozoon fertilizes a female-producing ovum, the result will be a female offspring, femaleness being by hypothesis dominant over maleness.

Reconcilable with other views is the theory expounded by Geddes and Thomson in *The Evolution of Sex* (1889), that what primarily settles sex is a difference in the rate or rhythm of metabolism. The male organism or sperm-producer is relatively the more disruptive or katabolic; the female or egg-producer is relatively the more constructive or anabolic. Perhaps this is the nearest that Biology has yet got to the true inwardness of sex!

CHAPTER XVII

WHAT IS PARTHENOGENESIS?

Virgin birth or parthenogenesis is one of Nature's short cuts. It means the development of an egg-cell without being fertilized by a sperm-cell. It is not a primitive state of affairs, but has arisen secondarily among animals and more rarely among plants, in types whose ancestors presumably showed, as their relatives certainly show, the ordinary mode of development from fertilized egg-cells. It was first proved, we believe, by the Swiss naturalist Bonnet, who showed in 1763 that the summer generations of green-flies or Aphides are all females, no males occurring for months. It is possible to have at least four years of continuous virgin birth without any male being present.

Parthenogenesis is of frequent occurrence, (1) in many of the lower crustaceans, such as the brine-shrimp *Artemia*, the large freshwater *Apus*, and some small "water-fleas," e.g. *Daphnia*, *Moina*, *Cypris*, and *Candona*; (2) in some insects, notably among the gall-wasps (*Cynipidæ*), in certain species of which males have not been found, and among saw-flies (*Tenthredinidæ*); and (3) in most of the minute Rotifers or Wheel-Animalcules. In most Rotifers parthenogenesis is the rule; in some species males have never been found; in some types in which they occur they do not fertilize the eggs. In most of the cases of parthenogenesis among crustaceans and insects, males are absent for months or years, but reappear at intervals. Among plants there are few examples of uninterrupted or complete parthenogenesis in the strict sense, for it is necessary to exclude relapses into asexuality, as seen, for instance, in many of the lower fungi, where the sexual reproduction has more or less degenerated. The

development of an egg-cell without fertilization is seen in *Chara crinita*, one of the water-stoneworts, which is represented in Northern Europe by female plants only. Parthenogenesis has come to be the rule in the common dandelion, and it also occurs in some hawkweeds and in a few other types, e.g. species of *Alchemilla* and *Antennaria*. It may be noted here that there is no reason whatever to associate the dominance of parthenogenesis with any loss of racial vigour. A hundred successive parthenogenetic generations have been carefully observed in the case of *Daphnia*, and there was no suggestion of any degeneration. In a few cases the occurrence of *variation* in forms produced parthenogenetically has been demonstrated.

It is useful to distinguish several different grades of parthenogenesis. (a) What may be called *pathological* parthenogenesis is illustrated when the egg-cell, say of a hen, exhibits without fertilization a number of divisions. In none of these cases has the development been known to go far. (b) The term *casual* parthenogenesis may be applied to cases where the occurrence is observed as a rare exception, e.g. in silk-moths. It occasionally happens that worker-ants, not normally reproductive at all, produce ova which develop parthenogenetically. Since the discovery of what is called artificial parthenogenesis (see below), these instances of pathological and occasional parthenogenesis have become more intelligible. (c) *Partial* parthenogenesis is well illustrated by hive-bees. The queen receives from the drone a store of male-elements or spermatozoa, and it rests with her, in laying the eggs, to fertilize them or not. Those eggs that are fertilized from the store of spermatozoa in her spermathecae develop into workers or queens (according to the nurture); those that are not fertilized develop into drones. The same is true of some other Hymenoptera, such as ants. (d) The term *seasonal* parthenogenesis may be applied to cases like

green-flies or Aphides, where one parthenogenetic generation succeeds another all through the summer, but males reappear in the autumn and fertilization occurs. This is also illustrated by some of the water-fleas. (e) The term *juvenile* parthenogenesis may be applied to some curious cases (e.g. in the midge *Miastor*) where larval forms exhibit precocious reproductivity without any fertilization. It becomes difficult, however, to draw a line between such cases and multiplication by means of spores, such as is seen in the larval stages of the liver-fluke and in many plants. Spores are specialized reproductive cells which develop without fertilization; they are familiar to everyone on the fronds of ferns. The formation of spores is a primitive mode of reproduction, but the parthenogenetic development of ova is probably in all cases secondary and derivative—a relapse from the normal spermic development. None the less it seems to work well in certain kinds of organisms and in certain conditions of life.

It may be asked whether egg-cells which normally develop without being fertilized are in any way different from ordinary ova. But the answer is not at present very clear. In some cases (ants, bees, and wasps) the ova go through the ordinary process of maturation, involving a reduction of the number of nuclear rods or chromosomes to half the normal number. In some other cases (Rotifers, some water-fleas, and green-flies) there is no reduction when the conditions of life are favourable, though there may be when they are unpropitious.

Of great interest and importance is the establishment of the fact that in a variety of cases the ovum may be artificially induced to develop parthenogenetically. The demonstration of this has been mainly due to Jacques Loeb and Yves Delage. If the unfertilized eggs of a sea-urchin be left for a couple of hours in sea-water the composition of which has been altered (e.g. by adding

magnesium chloride), and be then restored to ordinary sea-water, many of them develop into normal larvæ. A mixture that Delage found to be very effective for sea-urchin ova consisted of 300 c. cm. of sea-water, 700 c. cm. of an isotonic solution of saccharose, 15 centigrams of tannin dissolved in distilled water, and 3 c. cm. of normal ammoniacal solution. It works equally well if the volume of the sea-water or of the saccharose be doubled. The ova were left for an hour in the mixture, then washed several times, and then placed in sea-water, where they soon developed. In a few cases fully formed sea-urchins have been reared. There are two points of special importance—first, that the artificial parthenogenesis has been induced in a great variety of types, e.g. sea-urchin, starfish, marine worm, mollusc, fish, and even amphibian; and second, that the artificial stimuli effectively used are very varied—chemical, physical, and mechanical. Artificial parthenogenesis has been induced by altering the chemical composition of the water by adding or removing certain salts, or by altering the concentration by adding salt and sugar, or by subjecting the ova to various influences, such as superabundance of carbon dioxide, vapour of chloroform, ether, benzol and toluol, the presence of butyric acid, blood-serum, and extracts of foreign cells, or by exposing the ova to electric currents, or to mechanical stimulation. Bataillon has shown that frogs' eggs pricked with a needle and washed with blood may proceed to develop rapidly and normally. In a few cases the parthenogenetic development has been successfully carried beyond the completion of the tadpole metamorphosis. The effective stimuli, such as have been enumerated above, differ for different kinds of eggs and even for eggs of the same kind at different stages of ripeness. There is probably some common factor in all the effective stimuli, but what it is remains uncertain.

It is too soon to make more than a tentative statement as to what happens in artificial parthenogenesis. According to some, the artificial changes in the medium do not in themselves directly induce segmentation, but modify the intimate constitution of the egg in such a way that when it is returned to its natural medium it becomes auto-parthenogenetic. According to Loeb, the physico-chemical agency induces the formation of a "fertilization membrane" by a change in the surface of the egg comparable to that which follows the entrance of a spermatozoon. The first step is a cytolysis or partial solution of the cortical layer of the ovum, perhaps a liquefaction of fatty substances in the cellular emulsion. The result is the formation of the "stabilizing envelope," or "fertilization membrane." But the appearance of this membrane seems to lead to an acceleration of the oxidations going on in the egg; the egg is activated and segmentation begins. But this may simply lead to disintegration, if there is not also a corrective factor, and it has been possible to devise experimental conditions that induce activation only and others that induce activation followed by stable development. Thus the presence of a fatty acid, such as butyric, may bring about membrane-formation and the activation of the egg, while the presence of a hypertonic solution (i.e. with increased osmotic pressure) may serve as the essential corrective. The life of the activated egg may also be saved by putting it after the membrane-formation for about three hours into sea-water practically free from oxygen or containing a trace of potassium cyanide. In either way, the over-active oxidations in the egg may be suppressed. If the eggs are thereafter transferred into ordinary sea-water containing free oxygen they often develop normally. Similarly, pricking the ovum of a frog or toad with a platinum needle, so as to admit several blood corpuscles, may

serve to activate, while the return to the normal medium may serve as the indispensable corrective to disintegration.

One must not conclude that the rôle of the complex living spermatozoon is exhaustively replaced by the chemico-physical agencies referred to, for normal fertilization implies more than activation and a regulation of the subsequent cleavage. It implies a mingling of the heritable qualities of the two parents. What the experiments show is that the ovum is quite complete in itself, that certain factors involved in what the spermatozoon effects may be artificially mimicked, and that perfectly normal larvæ may be reared from various unfertilized eggs which are not known ever to develop parthenogenetically in natural conditions. The remarkable facts that have come to light since 1899 show that one cannot set limits to the possibility of the occurrence of parthenogenesis. Some of the experimental conditions which are effective in inducing parthenogenetic development might find a parallel in natural conditions. As yet, no instance of either artificial or natural parthenogenesis has been observed in the Animal Kingdom above the level of Amphibians.

There is something puzzling in the cropping up of parthenogenesis in so many different corners of the Animal Kingdom. It has not been discovered that any peculiarity characterizes those ova that are normally able to develop without being fertilized. There is no necessary degeneration associated with a long-continued or even perpetual parthenogenesis. Rotifers are minute, but the females are certainly not degenerate. Some instances of variability have been recorded in the course of parthenogenetic generations, which shows that dispensing with fertilization need not imply a full stop to further evolution. It may be that parthenogenesis, being a short cut, favours rapid multiplication, so that in

conditions of abundant food the variants exhibiting parthenogenesis would automatically tend to survive. It may also be that parthenogenesis is a distinct advantage in species where, for some obscure reason, the males are few and far between. But it must be confessed that in many, if not most, cases it is impossible at present to find a utilitarian justification of the parthenogenetic departure from the typical course of sexual reproduction.

But if the question be asked why there should be males at all if it is possible for so many different kinds of females to continue the race single-handed, part of the answer would be that having two parents is on the whole better than having only one, since there is a pooling of two inheritances, so that the father may compensate for some deficiency in the maternal contribution. Another part of the answer is that cross-fertilization is one of the conditions of new departures or variations—the raw materials for further evolution. Another larger reason for the ordinary process of sexual reproduction may be found in the fact that the egg's usual need for fertilization is wrapped up in most cases with the occurrence of dimorphic sexes, with reproductive division of labour, and that great consequences—psychical as well as physical—have followed from this primeval dichotomy. Sex has been a powerful factor in organic evolution.

CHAPTER XVIII

SPECIFICITY AND INDIVIDUALITY

How often we are brought back to this difficult but fundamental fact, that every different kind of creature is itself and no other. It is probable that every well-defined type has a protein peculiar to itself; but even within the type each species is peculiar. The blood crystals from the dried blood of a horse are different from those of a donkey. In the microscopic egg of one species of the deadly parasite *Bilharzia* there is a sharp spine at one end of the shell, while in another species it projects laterally. One species of rose has fourteen stainable rodlets or chromosomes in the nucleus of each cell of the body, while another has twenty-eight, and so forth. The newness that makes a new species is often detectable in many different parts of the creature. One species differs from another not merely in something striking that makes it worthy of a distinct name, but also in little trivialities which nevertheless breed true. A good example is forthcoming in a recent study by R. P. Wodehouse on the pollen-grains of composite flowers related to the camomile and artichoke. Many pollen-grains have an ornamented surface, sometimes covered with microscopic spines, and these roughnesses may be of advantage in enabling the pollen-grains to adhere to the hairs of insect-visitors or to the surface of the stigma of the appropriate flower. If that were all, one would think that a few different types of roughness would meet all the needs of the case. But that is not the way Nature works. In many cases the roughnesses differ in nearly related species. The individuality or specificity of the species may be expressed in the pattern of the pollen-spines! There is

variety in the number of spines and in their arrangement over the surface of the grain. In many cases they are absent altogether.

INDIVIDUALITY

When zoological distinctions between related types or genera or species are really satisfactory they express a contrast of individualities. No kind of living creature deserves a name to itself unless it has some idiosyncrasy. It must be chemically distinctive—having its own particular protein for instance; and it is satisfactory to know that the hæmoglobin crystals of, say, a wolf are demonstrably different from those of a fox. The difference must also be architectural, affecting everything from fine details of cell-structure upwards; and it is satisfactory to know that the cells lining the windpipe of a dog are demonstrably different from those in a similar position in a rabbit. Among Alcyonarian corals, of which we have made a hobby, the details of the spicules that form an armature around the polyps are often quite diagnostic; and many a field-naturalist can identify a bird from a single feather that it drops. A species should be in many ways itself and no other. Now it is a commonplace, but an important one, that this specificity will often express itself in unimportant details of habit. A good instance is given by Dr. Charles Hose in his fascinating *Fifty Years of Research and Romance* (1928). Dealing with his experiences in Borneo he contrasts the three ways in which three related animals will deal with a bowl of something drinkable placed before them on the ground. The Orang-Utan generally bends down and drinks out of the bowl without handling it. The Gibbon, also an anthropoid ape, dips one hand into the bowl, and then, throwing its head back, sucks the moisture off the hair on the back of the hand, repeating the process time after time till

its thirst is slaked. But the ordinary Macaque monkey, though farthest away from human kind, lifts the bowl up, if not too heavy, with both hands, and drinks out of it much as a man would. Of course, thousands of instances of this specificity of behaviour might be given; and it is an eloquent fact to be kept always in mind.

Everyone knows about finger-prints, which afford the best-known biological illustration of individuality. Each one of us has a particular pattern of ridges, loops, and whorls on the under-surface of our finger-tips; the pattern remains practically the same throughout life; and no one else has our particular pattern, unless perhaps our identical twin brother, but not always he! As is well known, the individuality of the pattern is so trustworthy that a criminal may be discovered and convicted on the strength of his previously registered finger-prints. But for the biologist the interest is theoretical, that in these details there is an expression—a scientifically describable expression—of individuality. The pattern of the ridges, loops, and whorls is an indication of that mysterious something that makes each man himself and no other. A bird species may be identified from a single feather, and a fish species from a few scales: that is *specificity*; but here we are dealing with the sign-manuals of the individual, with *individuality*.

What are these ridges that we often see glistening with droplets of sweat on a hot day—for the delicate openings of the glands are on their crests? They are coalesced rows of epidermal papillæ—like closely adjacent mountain-peaks united in a curved ridge. And if a hypothetical ultra-delicate needle could be inserted perpendicularly through one of the epidermal papillæ (coalesced in ridges) it would pass through the epidermis into the under-skin or dermis *between* two of the dermal papillæ.

That is to say the innermost part of an epidermal papilla has a dermal papilla on each side of it, so that there is a kind of interlocking, which may possibly have some physiological value in increasing the mechanical firmness of the skin and its intricate cellular fibrils, or its nourishment from the capillaries, which do not pass beyond the dermis, or even the thoroughness of the innervation. This seems to be an obscure question, but surely many books have made an unnecessary mistake in saying that the epidermal papillæ correspond to the dermal papillæ, whereas they really alternate with them. Does not the crest of an epidermal ridge correspond to the valley between two dermal ridges?

With a lens, or even with the naked eye, one can see that the apertures or pores of the sweat-glands are on the crests of the ridges, as was noticed by Nehemiah Grew, one of the pioneer microscopists, as far back as 1684. Herbert Spencer had not observed this, however, and in talking to Galton and cudgelling his brains to find some meaning in the ridges and valleys, he suggested that their significance was that the ridges protected the delicate sweat-duct openings which lay in the valleys. When Galton genially remarked that, unfortunately for the theory, the openings were on the *crests* of the ridges, Spencer "laughed uproariously." He then told Galton of Huxley's definition of a Spencerian tragedy—"a beautiful theory destroyed by an ugly little fact." And there's a moral here for most of us!

In any case, when we next look at the imprint of a child's buttery fingers on the margin of a fair page, or our own sign-manual on a flagon, or the ridges on our thumb glistening with droplets of sweat, let us realize that here is a problem to work at—the problem of individuality. The use of the ridges and valleys on the

naked parts of the skin is doubtful; the conditions of development and growth that induce them are quite obscure; they have a pre-human origin, for simpler patterns are seen in apes and monkeys; but why are yours yours and mine mine? There's the rub.

CHAPTER XIX

WHAT ARE ENZYMES?

Man's knowledge of ferments is modern, but his knowledge of fermenting is ancient. Vines were being cultivated and wine was being made by 3500 B.C., if not much earlier, and wine-making implies familiarity with fermentation. The juice of the grape, pressed out and left to itself, soon begins to bubble and froth. It gives off carbonic acid gas and "boils up," and this boiling-up is what the word "ferment" refers to, with the same root as in "fervent." The sugar of the grape is changed into alcohol; hence wine.

There are other fermentations of ancient origin, such as the making of vinegar out of weak alcohol exposed to air. In the course of a few days a slimy mass appears on the surface, and we now know that this, called "mother of vinegar," is made up of acetic acid bacteria entangled in a slimy substance which they produce. Very old also are the drinks produced from milk by lactic acid bacteria, sometimes with the addition of yeasts. The case of "Kefir," which is prepared from milk by adding "Kefir grains," is interesting because there is here, as far back as Mohammed, the introduction of an extraneous something to produce the fermentation. The "Kefir grains" are now known to be little packets of lactic acid bacteria and yeasts.

Similarly the fermentation in dough, which brings about the evolution of gas and makes the bread spongy, is due, as everyone knows, to the introduction of the "leaven," that is, some dough reserved from a previous baking and rich in yeasts, or to the introduction of yeast bought from the brewer.

That the juice of the grape seemed to be sufficient unto

itself, requiring nothing to be added, is intelligible enough nowadays, for we know that there are always "wild yeasts" in the soil of the vineyard, which get carried on to the grapes by insects, and will set up fermentation in the vat if they are allowed this opportunity.

The Dutchman Lceuwenhoek, one of the most extraordinary observers who have ever lived, was the first to see not only yeast-plants but bacteria. This was towards the end of the seventeenth century; but it was not till about 1835 that the French physicist, Cagniard de Latour, recognized that yeast was composed of living cells that multiplied rapidly by budding. He suggested that they probably acted on sugar through some effect of their vegetation. But a firmer step was taken about twenty years later, when Pasteur proved incontrovertibly that alcoholic and lactic fermentations were due to the action of two living organisms, the yeast-plant and a lactic acid bacterium respectively. This was an epoch-making step.

For many years a distinction was drawn between ferments like those of the digestive juices—the pepsin of the stomach, for example—and ferments which are living organisms themselves, like yeast-plants. Rennet, which one buys in a shop when one wishes to make curds, is a preparation of the lining of the calf's stomach. It acts on milk as a coagulative of the cheesy material, and it is almost, if not quite, the same as pepsin. No one regards it as in any way alive, as the yeast is, whether used for making bread or beer. But the distinction between unorganized and organized ferments was broken down by Buchner in 1897, for he showed that a yellowish juice extracted from killed and crushed and excessively pressed yeast has considerable power of fermenting sugar. Thus the yeast-plant is able to ferment sugar not because it is alive but because it contains a ferment. Extracts of

a few fermentative bacteria have also been prepared. Buchner's important demonstration was marked by the replacement of the term "ferment" by "enzyme," which is applicable to the fermenting chemical substance whether it works inside or outside living cells.

But in what way are enzymes peculiar? They quicken chemical reactions, often prodigiously; they do not enter into combination with the substance that is formed as the outcome of the fermentation; a small amount, given sufficient time, is as effective as a large amount ("a little leaveneth the whole lump"); a very minute amount will serve; thus a spoonful of rennet will clot 400,000 times its weight of the cheese-forming substance (caseinogen) in milk; in most cases their actions are "reversible."

The last point is difficult and requires some explanation. In many a mixture when a ferment is splitting up a substance—untying a knot—there is another change in progress working in the opposite direction and tying the knot. At a certain point the splitting-up and the building-up attain the same velocity and no further change occurs, a condition of equilibrium having been established. If the products of a fermentative action are removed as they are formed, and new fermentable material is provided, the enzyme goes on unexhausted. This is called the inexhaustibility of enzymes or ferments.

A combination of oxygen and hydrogen to form water comes about at ordinary temperatures and at atmospheric pressure when the two gases are brought together in the presence of spongy platinum, which has an enormous internal surface in proportion to its volume. On that surface the oxygen of the air is brought into very close quarters with the condensed hydrogen, and union takes place. These inorganic substances which facilitate chemical changes without being themselves used up are called catalysts; and enzymes are like organic catalysts. It may

be that the colloidal ferment supplies a suitable surface on which a reaction takes place, but it is also possible that the ferment enters into temporary union with the substance that is being changed, and then gets free again to combine with more.

The nature of fermentation remains in great part a secret. When it is discovered it will bring science nearer an understanding of the secret of Life itself. For it is certain that vital changes depend in great part on ferments, which admit of very rapid action within small compass by minimal quantities which are not exhausted by the changes they accelerate.

As is well known many animals, like fire-flies, produce a cold light, badly called phosphorescence. In some cases, as in certain cuttle-fishes, the organ which produces the light is found to be crowded with bacteria, and it looks as if they were the photogenic agents. Everyone knows the luminous bacteria that make dead fishes shine in the dark. Unfortunately, the bacteria taken from a luminous organ do not give off light, but this may be because they are removed from their natural environment. On the other hand, there are animals in which light is produced without any evidence of partner bacteria. This is the case in fire-flies, and in various small crustaceans of the open sea, and in the boring bivalve called the Piddock or *Pholas*. In these cases there seems to be an interaction between two kinds of substances, one called luciferin and the other luciferase. A recent study of luciferin by a Japanese biochemist, Sakyo Kanda, corroborates the view that this substance is a protein. The investigator got his material from a beautiful little crustacean called *Cypridina* which swarms near the surface of the open sea. What use the luminescence may be to the crustacean is not known, and the same remark may be made about most of the luminous animals. The luciferase seems to

act like a ferment on the luciferin, and the fermentation is accompanied by a rapid oxidation. The study of bioluminescence is being vigorously pursued, for some settlement must be arrived at between those who declare it to be due to partner bacteria and those who maintain that the light is produced by a fermentation process apart from any microbes. Moreover, man, who always wishes for more light, may gain something by imitating luminescent animals, for their light is without any heat rays.

STANDING THE HEAT

In north temperate countries we seldom experience anything that approaches the fierce heat of the deserts, where there are no clouds to form a curtain, and where there is no vegetation to screen the ground, which becomes as hot as an oven. There is a vegetarian lizard called the Chuckwalla, of Californian deserts, which sits upon rocks when they are too hot for the hand to touch; and the Agama lizard, which frequents Ur of the Chaldees, is another of those heat-loving animals that bask in the sun like the mythical salamander. But this power of resistance belongs to the minority; most animals in hot deserts show some sort of adaptation enabling them to circumvent the high temperature.

Mr. R. A. Buxton, in his *Animal Life in Deserts* (1923), tells us that in the heat of the day many animals hide under stones or in burrows, and that sparrows and bulbuls bury themselves in the dense mass of leaf-bases and young shoots which spring from the crown of the date palm. One of the Mesopotamian jerboas, most elegant and agile of mammalian bipeds, burrows steeply for two or three feet into the earth, and remains in hiding till night-fall. For that is another not infrequent evasion of the heat—to become nocturnal. The Horn Expedition to Central Australia observed that if the lizard *Tiliqua* was taken from its hole and put on the sand at noon, it ran a few yards and rolled over dead, and similar examples might be multiplied.

What is true of many full-grown desert animals holds also for eggs—exposure to the sun is apt to be fatal. In most cases, therefore, they are hidden away; or, in the

case of a few desert birds, like sand-grouse, sheltered by the self-forgetful parents. It must be a very exacting parental sacrifice to brood in the heat of summer on the bare ground. We can understand the value of the shadow of a rock or even of a bush. In the case of the ostrich, which does *not* bury its eggs in the sand either in Africa or Arabia, the thick shell appears to offer sufficient protection. Mr. Buxton writes: "The eggs are often left entirely uncovered and exposed to the heat in the middle of the day, particularly in the hotter parts of the bird's range. At other times of day, and particularly in the colder parts of the bird's range, the eggs of the ostrich are incubated by both parents in turn." Small eggs with relatively thin shells are soon killed by exposure. There is a pretty point in connection with sand-grouse, where the two parents brood alternately. The bird who is off duty flies to a watering-place and, standing in the shallow water with its short legs, gets the breast and under-parts well saturated. When it relieves its mate, the eggs and the soil are, of course, wetted, and this tends to prevent overheating. In some species, at least, the young sand-grouse get the necessary water by pressing the wet parental feathers through their bills, and until they are able to fly this is their only way of satisfying their thirst. But we must not continue along this line; it is plain that many living creatures are made uncomfortable by the heat.

Except in birds and mammals, it is the rule among animals that the temperature of the body tends towards that of the surroundings. When it is cold outside, it tends to be cool inside; when it is hot outside, it tends to be warm inside. The body temperature is changeful and approximates to that of the environment; and this is what is meant by being "cold-blooded." It is a serious imperfection, especially for animals that require to be vigorous, for it gives the environment a powerful grip. If the outside

temperature passes beyond certain limits, which vary greatly for different animals, the only alternative to death is to lie low and say nothing. Thus many of the lower animals pass into a state of lethargy when it is very hot or very cold. There are, indeed, some mitigations of the imperfection, such as a non-conducting covering to the body, as we see in the hairy coat of a humble-bee, or the thick shell of a snail, or the slime on a slug. Everyone is familiar in summer with the frothy masses which surround the young frog-hoppers on the grasses. By whipping the air into intimate mixture with an overflowing sweet juice, along with a little digestive ferment and a percentage of wax, the frog-hopper is able to make a kind of soap which lasts, and protects it both from enemies and the heat of the sun. This is its peculiar way of keeping cool.

In birds and mammals, however, there has arisen a heat-regulating arrangement which we call "warm-bloodedness." The temperature of the body remains constant day and night, year in and year out. We may say that we feel cold in winter or warm in summer, but our body temperature is the same—or almost the same—always, so long as we are in good health. This power of retaining an equable internal temperature is one of the great acquisitions of birds and mammals. It makes them independent of their surroundings, as regards temperature, in a way that is quite impossible for the so-called "cold-blooded." We are not surprised that the heat-regulating arrangements are not well established in most young birds (as also in many young mammals), which must be kept well wrapped up in the nest if the weather is cold, or protected against the sun in the fierce heat and glare of the tropical desert. If a brooding bird that has left her nestlings for a little is prevented from returning, they soon die, for they are imperfectly warm-blooded.

Similarly there are a few kinds of mammals that never attain to the perfection of warm-bloodedness that characterizes all the others; and it is among them that we find hibernation (winter sleep) and æstivation (summer sleep)—a remarkable relapse towards the ancestral reptilian condition. But this weakness has been counteracted by becoming linked to the habit of hiding away in confined spaces and lying in a state of collapse until the external extremes of temperature have passed. Hedgehog and marmot, dormouse and bat, are well-known examples of hibernators. The tenrec of Madagascar, a relative of the hedgehog, illustrates what seems to be an analogous condition of summer sleep or æstivation. If this summer sleep is of the same nature as winter sleep, it must be separated off from the heat torpor exhibited by many cold-blooded animals, like some lizards, snakes, toads, fishes, and snails. In his *Voyage of the "Beagle,"* Darwin speaks of very hot days in Brazil: "With this high temperature almost every beetle, several genera of spiders, snails, toads, and lizards were all lying torpid beneath stones." This is *their* way of keeping cool.

The heat of our body is mostly produced by the muscles, under the regulation of a special centre in the brain. If the mammal, such as one of ourselves, is losing much heat into the cold air, the temperature of the blood falls a little. But when this slightly cooler blood passes through the heat-regulating centre in the brain, there is an automatic stimulation, and the centre sends orders by the nerves to the muscles, commanding them to produce more heat. In a short time, if things go well, the equable temperature of the body is restored. This makes it easier for the chemical processes involved in living to go on quickly and smoothly. But if the weather is very hot, and the temperature of the body tends to rise unduly,

there are various things that may happen. The creature may remain very still, and that lessens the production of animal heat. It is when Europeans are obliged to move about actively in the heat of the day in tropical countries that they suffer badly, sometimes fatally. Secondly, the creature may automatically begin to breathe more quickly, more air passing in and out of the lungs, and this tends to lower the temperature of the blood, which is spread out on a large surface in the interior. The "panting" movements of many mammals are familiar, and the dog with its tongue lolling out of its mouth is also cooling its blood. And again, under orders from the brain, which is stimulated by unusual changes in the temperature and composition of the blood, the sweat-glands begin to pour out drops of water. They are filtering it out from the surrounding blood-vessels, and the evaporation of the sweat lowers the temperature.

In birds there are no sweat-glands, so their way of keeping cool must be to some extent different from that of ordinary mammals. They seek the shade; they keep quiet in the great heat; they also pant. There is an internal system of air-sacs connected with the lungs, and on the walls of these there seems to be an "internal perspiration" which will counteract the tendency to feverishness.

For ourselves, if we are disturbed by the heat, the obvious precautions are four: (1) not to do anything unnecessary in the way of exertion when it is very hot; (2) to keep the skin in perfect condition so that the evaporation of water by means of the sweat-pores is easy; (3) to adjust the clothing so that it facilitates the loss of heat and does not fit the skin too closely; and (4) to adjust the diet so that we eat smaller quantities of the heat-producing foods.

There is another kind of "keeping cool" of a much

subtler sort, which depends on many factors, such as a well-controlled nervous system and mind, harmoniously working glands of internal secretion, a methodical way of anticipating situations, and more besides. But this is quite another story.

CHAPTER XXI

HOW DO WE CATCH COLD?

It is a sign of the times that one of our foremost physiologists should be joint-author of a book on *Common Colds* (Professor Leonard Hill, F.R.S., and Mark Clement. Heinemann, 7s. 6d.). It is an instance of bringing science to bear on common handicaps to efficiency and happiness. "Colds are the cause of an immense amount of ill-health and economic loss; education in the laws of health is the means of combating this loss."

There is no close connection between a cold in the head and a cold day or a cold room. Arctic explorers do not usually catch cold till they come home! A cold is the answer-back that the lining of the nasal passages makes to intruding microbes, which may be of many different kinds. A cold is a reaction to an infection, and the infection comes oftenest in air-borne "droplets" from infected neighbours.

No doubt a spell of cold weather may be followed by an epidemic of "colds," but that is because coddling in over-warm rooms or inside too many layers of clothes, or some depression of the body, e.g. through lack of exercise, fresh air, and sunlight, has weakened our power of resistance to intruding bacteria. An expert writes:

Chill in pure air has nothing whatever to do with catching cold. You may get wet to the skin, sit in through draughts, spend nights in an open boat, you will never get a common cold; bronchitis and rheumatism you may have, but a common catarrhal cold never, without direct infection.

It would be foolish indeed to spend a night in an open boat except when one was in good health and spirits—able to answer-back, for instance, to an unusual loss of

animal heat—but the point is that an ordinary cold implies an infecting microbe and a suitable internal soil, in the nasal chamber or the like, in which the germs may grow and multiply.

When the cold-microbes get into a suitably sensitive nose they settle down and begin to multiply. But it takes a little time before they are numerous enough to provoke the surrounding tissues. This so-called latent period of infection is often about two days, but the period varies with the nature of the microbe and with the state of the patient. Although the infected person is only feeling a little out of sorts, the invaders are hard at work, and this early chapter is said to be the usual time for infecting other people.

The second chapter is marked by abundant exudation from the lining membrane of the nasal passages, that is to say from living cells which are being provoked, poisoned, or disintegrated by the intruding microbes. In some cases the inflammation, as it is called, is marked by a vigorous defence on the part of our bodyguard of wandering amoeboid cells or phagocytes.

In a day or two, if the bodyguard cells are unable to cope with the invaders, the nature of the secretion changes. It becomes less liquid, and more disagreeable; it often contains numerous broken-down cells. The lashed or ciliated cells of the nasal passage try to sweep particles towards the back of the mouth, but the task is often beyond their powers. The nasal passage may become blocked; the handkerchief is much in evidence; the cold gets worse and worse; and the infection may spread to other parts.

In conditions of positive health the intruding microbes are likely to be killed by the secretions of the body—such as the mucus in the nose, the saliva in the mouth, and even the tears from the eyes. As already said, the primary

use of tears is to moisten and clean the outside of the eyeball, but they also play a useful part in destroying bacteria. Their use in expressing grief is a tertiary function!

If the secretions fail to balk the invaders, the second chance is that the phagocytes, which are mobile and militant white blood corpuscles, will engulf and digest them. And here man may try to help by using local antiseptics in the nose and mouth, or by taking tonics which brace the body to greater resistance. But "a cold once established has to run its course until the natural resistance of the body effects a cure."

The British public has a strong faith in alliterative advice, such as "stuff a cold and starve a fever," and this familiar one is widespread. It was not so bad to start with, for it ran: "If you are fool enough to stuff a cold, you will produce and have to starve a fever." But "the original sound warning has been inaccurately abbreviated into a harmful piece of advice which no one should follow."

Luckily, however, the heavily colded patient has rarely any desire to be stuffed, partly perhaps because he can no longer scent the flavour of the food. Of course, stuffing is never any good for anything!

It is to the credit of modern medicine that while it is interested in cure, it is still more interested in prevention; and the best authorities assure us that the frequency of colds can be lessened "by securing pure air and sunlight, and discipline in living a healthy life, particularly in regard to diet, exercise, rest, and clothes."

It has been shown experimentally that animals brought up on a diet deficient in Vitamin A are very subject to diseases comparable to our "colds"; and ill-feeding has a similar prejudicial effect on man. Crowding, lack of ventilation, scanty sunlight, insufficient exercise, a low standard of cleanliness and of manners—these and the

like increase the incidence of colds, which, bad enough in themselves, often lead the way to more serious maladies. The only use of a "cold" is to warn us that unless we improve our positive health we shall soon have something worse.

When the householder suspects an escape of gas, yet is not very sure that it may not be the hidden presence of a dead rat that he has to detect, he "sniffs." In other words, he draws a current of air somewhat forcefully into his nasal chamber, so that the sparse gaseous molecules diffused in the air may impinge on the "olfactory patches" on which there lie the nerve-cells that are sensitive to "smells." In dogs and some other animals the process of sniffing is familiar, and it is utilized not only to make sure of the presence or absence of a certain odour, but to determine the location of the odoriferous body. By movements of its head, associated with tentative sniffings, the dog can discover the direction taken by the rabbit or by its master. Now this power of sniffing is very old. It may be seen in newts when they are testing a piece of food, such as earthworms, thrown into the aquarium. But here the external medium that is drawn into the nostril is, of course, water. Even before amphibians, however, the habit of sniffing began, namely, in the mud-fishes or double-breathers (*Dipnoi*), which are lunged as well as gilled. The origin of "sniffing" has been traced back to the African mudfish, *Protopterus*. What bundles of antiquities we are!

CHAPTER XXII

WHAT ARE FILTERABLE VIRUSES?

What are these "filterable viruses," which have been so much investigated in recent years? The first to be recognized was that which causes "mosaic disease" in the tobacco plant. It was shown that a healthy plant could be inoculated with filtered juice from diseased leaves, and it was noticed that the juice retained its virulence for many months. But it was not till six years afterwards that the importance of the new idea was recognized. In 1898, Loeffler and Frosch showed that fluid taken from the blisters of animals suffering from foot-and-mouth disease was capable of producing the characteristic symptoms after it has been passed through a fine porcelain filter which kept back ordinary microbes. It was suggested that many familiar infectious or contagious diseases, in which it had been found impossible to detect a microbe, might be due to filterable viruses. The list of diseases now included under this heading must be at least fifty. As instances we may mention measles and scarlatina in man, pleuropneumonia and rinderpest in cattle, chicken plague and silkworm jaundice, and mosaic diseases in many plants like tomatoes, beans, and sugar corn. It is probable that the filterable viruses do not form a homogeneous group. Thus it is probable that some contain an enzyme (or ferment) which does deadly dissolving work, and increases in amount so long as it has abundant material on which to operate. In most cases, however, the probability is that we have to do with living organisms comparable to virulent Bacteria and Protozoa, but probably simpler than these. In some viruses, by using devices like centrifuging and the ultra-microscope,

corpuscles have been successfully demonstrated. In the disease called chicken plague they have been measured and found to be smaller than our red blood corpuscles. In some instances the use of an "ultra-filter" robs the fluid of its virulence, which supports the view that this is due to the presence of micro-organisms. In the spreading of "mosaic diseases" from plant to plant, sap-sucking and leaf-eating insects play their part, and a good illustration of the wheels within wheels may be found in the fact that insects may themselves become victims. Thus the wilt diseases of the caterpillars of the Nun moth and the Gypsy moth are due to filterable viruses, and these two cases are interesting because the results are in man's favour, not against him. The Gypsy moth caterpillar was accidentally introduced into America in 1869, and has done prodigious damage in defoliating trees. It is said that the appearance of wilt disease has probably done more to bring about the eradication of the pest than all man's efforts at control, energetic as these have been.

CHAPTER XXIII

WHY ARE WE NOT MORE FREQUENTLY INFECTED?

Many diseases, as everyone knows, are due to virulent microbes which find their way into the body and run riot there, it may be in the food-canal, or in the blood, or in various tissues. These microbes are usually Bacteria—inclined to the Plant Kingdom, as in the case of tubercle, smallpox, plague. But the disease-causers may be microscopic animals, like the malaria and the sleeping sickness microbes. In cases like foot-and-mouth disease, where the demonstration of a microbe seems still uncertain, it is safer to speak of an ultra-microscopic or filterable "virus"; but the probability is that here also we have to do with a living organism that invades the body.

Opposing the hostile microbes there are outer ramparts, notably the skin; hence the danger of little wounds, which are like breaches in the walls and allow the beleaguering enemies to find entrance. There are also inner ramparts, such as the digestive wall of the food-canal, and the lining membrane of other internal surfaces, such as the lungs. If these ramparts are broken down, and the assailants get into the city, which is the body, then there is fighting in the streets and things become very serious both for man and for beast. The assailants produce deadly poisons, and they are also able to break down important tissues, making gaps or lesions. An invisible microbe, which may be seen magnified inside the letter "o" of this word, may be the progenitor of a million in twenty-four hours. A cat may look at a king, but a microbe could soon kill a mammoth if there were any to kill. The tragedy is very familiar, but it never loses poignancy; a fine

organism—whether man or beast—brought to the dust in a few days or even hours by a contemptible invisible microbe!

Two of the internal defences of the body are well known. The blood is able to produce antitoxins which balk the toxins of the microbes. Set a thief to catch a thief; one secretion checkmates another secretion. Roux and Yersin demonstrated the toxins produced by bacteria; Behring and Kitasato proved the importance of the antitoxins which are the organism's answers-back; Roux and Martin showed how antitoxins may be produced by mild infection in an animal and kept in readiness to be injected into another animal when that is infected, or when the risk of its infection is great. Antitoxins have not been isolated as yet, and we must not be too sure that they are definite substances that *can* be isolated. It may be that they are merely properties or qualities of the colloidal equilibrium of the blood. Theories abound, but no one is sure—or rather no three people are agreed—as to how antitoxins work against toxins. It must be in some complex, physico-chemical fashion.

The second internal defence is on the part of phagocytes—wandering amoeboid cells of good appetite which engulf and digest virulent intruders. They are found in almost all animals, from sponges to man, and in backboneed animals they represent particular kinds of white blood corpuscles which are able, if need be, to leave the vessels and pass into surrounding tissue. Whenever there is any inflammation, that means that a struggle is going on between the bodyguard of phagocytes and the assailant microbes. The phagocytes belong to the body and they have other functions besides engulfing bacteria; thus they may help in replacing a part that has been lost, or in a great change of structure like that which occurs between a maggot and a fly. In the conflict between

phagocytes and bacteria the issue is sometimes affected by the production of "opsonins," which seem to paralyse the bacteria so that they become more readily the prey of the phagocytes. Some say that the opsonins whet the appetite of the phagocytes. Opsonins have not been isolated, and it may be that they merely represent a particular aspect of the work of antitoxins.

It is understood, then, that if one of our domesticated animals or one of ourselves be attacked by a virulent microbe, the issue depends on the formation of antitoxins by the blood and on the activity of phagocytes.

CHAPTER XXIV

HOW DOES OUR HAIR TURN GREY?

Whiteness is due to the almost complete and uniform reflection of all the rays that make up diffuse sunlight. This complete reflection may be due to the surfaces of little crystals, as in table salt, each acting like a miniature mirror. Or the reflection may be from the surface of microscopic platelets, as in the case of white fishes, whose familiar silveriness is due to very numerous flat cells in the skin which are laden with a nitrogenous waste-product called guanin. The whiteness of foam is due to reflection from the filmy surfaces of the innumerable air-bubbles which are entangled in the water, and it may be noted that a stream tumbling down the side of a snow-covered mountain in a series of cascades stands out from a distance as distinctly whiter than the surrounding snow!

The whiteness of a lily or a narcissus is due to the complete reflection of the light from gas-containing vacuoles between the cells of the perianth, and if we squeeze a piece of the flower very hard between our finger and thumb we drive out the air and are left with a transparent shred. Similarly a hair or a feather is white because of numerous gas-containing vacuoles which act like little mirrors. Usually these gas-bubbles replace the pigment that is normally deposited; in other cases, when a little pigment is present, it is masked by the bubbles.

A pigment may be defined as a chemical substance that affects the completeness of the light that is reflected from it or that passes through it; but whiteness in living creatures is hardly ever due to a pigment. A white

butterfly is white because of reflection from minute deposits of uric acid; a white rat is white because of the gas-bubbles in the pigmentless hair; splashes of white on the skin of a few animals may be due to an underlying deposit of fat.

In ninety-nine per cent. of cases the whiteness is produced by the complete and uniform reflection of the light from crystals, or crystal-like particles, or gas-containing bubbles. In short, whiteness is structural, not pigmentary, coloration; it is comparable to iridescence or metallic sheen, which is due to the fine structure of the surface on which the light falls.

The common stoat, first cousin of the weasel, is reddish-brown in summer, but in northern countries and at high altitudes it changes in winter into the ermine, snow-white except the tip of the tail, which is black all the year round. In the Highlands of Scotland the stoat always becomes an ermine, but the change of colour does not occur in Ireland and is rare in the South of England.

It is interesting to notice that ermine may be seen all the year round on the summit of Ben Nevis, which seems to clinch the conclusion that the cold is the external condition that pulls the trigger inducing the whiteness.

What happens seems to be that a moulting of hair occurs, as is common among mammals, in the autumn, and that the new suit of hair is developed with gas-bubbles in place of pigment, or with so many gas-bubbles that the presence of some pigment is disguised.

On some parti-coloured specimens, caught at the beginning of winter, the new white hairs can be seen short and strong. They are being developed under physiological conditions slightly different from those that operate in spring, when the white hairs are moulted off and new red ones take their place. The redness is due to deposits of a pigment called melanin, which can be traced

back to the action of a ferment (tyrosinase) on an amino-acid (tyrosin) derived from the proteins of the food. We must add, however, that the description of the blanching here cited from the old Aberdeen zoologist MacGillivray does not exclude the possibility that an individual hair of the stoat may occasionally become whitened, as in man.

No doubt there has been some exaggeration of the protective value of white colour not only to the ptarmigan but to the ermine and the mountain hare, for sometimes when the snow thins the blanched creatures stand out very conspicuously. Moreover, the stoat has very few enemies, and the permanently white polar bear has none. So that, without denying the occasional use of the white robe as a cloak of invisibility, we look for some deeper utility. And that may be found in the fact that for a warm-blooded animal in very cold surroundings the dress that preserves most of the precious animal heat is a dress of white fur or white feathers.

When man's hair becomes gradually grey, while still growing and being cut, the silvering means that the new growth at the base of the hair is developed with little or no pigment. In some cases Metchnikoff found evidence that wandering amœboid cells, called phagocytes, travelled into the hair and carried off particles of pigment. But when man's hair turns white in a night it has been shown that a marked and sudden development of gas-bubbles serves to mask the pigment which is still present. How variedly complicated all these simple things are!

WHY MUST WE DIE?

It is to some extent within our power to determine what we shall *not* die of, but die we must. It is also to some extent within our power to determine whether we shall come to a premature end or reach threescore years and ten; but sooner or later we must all die, as an apostle of the obvious might say. Yet why is this inevitable mortality such a foregone conclusion, since we are so fearfully and wonderfully made, and since it is characteristic of the living creature that it winds up its clock almost as fast as it runs down? What is it that makes death to all appearance intrinsically necessary in all organisms above the unicellulars? And the fact that we have to make an exception gives poignancy to our problem: Why must we die, when the Protozoa escape? Let us begin with the exceptions.

The phrase, "immortality of the Protozoa," which is due to Weismann, is not above reproach, for "immortality" is a religious or theological idea, and was not in the Freiburg zoologist's mind when he spoke of the "Unsterblichkeit" of the simplest organisms. He meant that the unicellular animals and plants are exempt from natural death. One might say that they enjoy a bodily immortality, were it not that they have not in the strict sense any body at all, but remain at the level of single cells—unit corpuscles of living matter which are physiologically complete in themselves. It was the evolution of a "body" that led to natural death. Death was the price paid for a body.

If death be defined as the irrecoverable cessation of the bodily or protoplasmic life of an organism, we may proceed to distinguish its three main forms—*violent*,

microbic or *parasitic*, and *natural*. In the case of violent death something occurs that hopelessly shatters the organism or some essential part thereof. A bullet may crash through a bird's heart or brain; a dislodged stone may fall on a crab in a shore pool and bruise its body fatally; one animal may be burned and another drowned; and one of the commonest forms of violent death is being devoured by some other creature. This is very obvious, yet it is not generally realized that most wild animals come to a violent end. A fish goes on growing and growing, older and older, without showing any senile changes, escaping one chance of death after another, until in most cases it becomes the prey of some larger fish or some other kind of animal such as a carnivorous turtle, or an otter, or a toothed whale.

It is not usually through any constitutional defect that an animal comes to a violent end, though the end may come earlier if the animal is sluggish or dull. Animate Nature is based on a system of successive incarnations, one creature depending on another for sustenance throughout wide circles; and it is difficult to imagine the ascent of life on any other plan, especially since the lower forms tend to multiply so much more rapidly than the higher, and would speedily swamp these if they were not kept in check by the ceaseless conjugation of the verb "to eat." And those who recoil from the fact that most animals come to a violent end should keep in mind that these violent ends are in most cases instantaneous. Moreover, those who reproach Nature, if not also its Creator, because a carnivorous cat devours an engaging warbler should also, if consistent, deplore the tragedy by which mosquitoes are reincarnated by the million into birds. In any case, the fact is that most wild animals die a violent death, and the unicellular Protozoa are not in any way exceptions to this rule.

Weismann's doctrine of the "immortality of the Protozoa" did not mean that they were in any sense exempt from violent death. Many are devoured; many are dried up by the sun; many are crushed, and so on, and this "violent death" continues through the whole of creation. It is a fact of observation, however, that wits are often successfully pitted against fatal accidents and vicissitudes, and even against the common contingency of being devoured; and this tilt with death finds its most effective expression in man—if we take account of the manifold risks he runs.

The second kind of death is due to the invasion of the body by certain microbes or by larger organisms which do fatal damage. Some of the microbes are bacteria, such as those which cause plague, cholera, tuberculosis, and diphtheria; others are virulent Protozoa, that is to say unicellular animals, such as those causing malaria and sleeping sickness; and there is a third group of organisms of extreme minuteness, the "filter-passing viruses," such as those associated with foot-and-mouth disease, distemper, measles, mumps, and probably cancer. The disastrous effects of a bad infection with virulent microbes may be a breaking down of certain tissues of the body, e.g. the walls of the lung; or a destruction of blood-cells, as in malaria; or a blocking of important passages, like the windpipe; but oftenest the damage is due to poisons or toxins which the microbes directly or indirectly produce. As everyone knows, many of these toxins in man and his domestic animals have been successfully checkmated by the artificial introduction of antitoxins.

Larger intruders, especially parasitic worms, are often fatal when they find entrance into hosts that are unaccustomed to them, or have no natural defences against them, as happens when hookworm and Bilharzia find

entrance into man. They may perforate important structures, or block passages in the body, or levy toll on the blood and digested food, or produce poisons, repeating on a big scale the injuriousness of microbes.

Yet it is noteworthy that in Wild Nature there tends to be a give-and-take compromise established between the parasite and the host, so that, in the majority of cases, the intruder does little harm. Infection with parasites is very common among wild animals and wild plants, yet it does not often happen that the intrusion is followed by those disintegrative and deteriorative processes that we call *disease*. When disease in the strict sense follows parasitism in wild organisms there has usually been some interference on man's part. Thus the so-called "grouse disease" may follow over-preserving, and the so-called "salmon disease" may follow contamination of the river. When the victim's constitution has been enfeebled by over-sheltering, over-crowding, over-exposing, and so forth, then the resident parasites may run riot and prove fatal; or the same may happen if the parasites find access to a new kind of host. Most parasites in Wild Nature establish a *modus vivendi* with their wonted hosts, and few of them cause actual disease, if we mean by disease the disintegrative and deteriorative processes which seriously disturb the normal harmony of health.

This large fact of Natural History must be kept in mind in connection with *human* mortality, for death often occurs in mankind (as also in domesticated animals and cultivated plants) as the result of intruding microbes and parasites, whereas this is rare in natural conditions.

The most characteristically human mode of death is "natural"; and this comes about by the slow mounting-up of unrecuperated arrears of wear and tear in essential organs. Modern research points to the conclusion that

while this nemesis is not intrinsically necessary, it has become almost inevitable in highly specialized organisms with much division of labour.

From youth onwards there is in many animals a cumulative wear and tear in hard-worked organs, and while this is counteracted by the rejuvenescent processes of rest, sleep, nutrition, and change, the active organism has a tendency to go into debt to itself. Unrecuperated arrears mount up, and when they exceed a certain (very variable) amount, natural death is inevitable. In the longer or shorter race of life, senescence always wins against rejuvenescence, except in the unicellular organisms and some doubtful exceptions. For it must be noticed that there are various animal types, such as many fishes and reptiles, that are not known to exhibit any senescent changes in their tissues, even after attaining to a great age. Even in the common voles of the countryside there does not seem to be any ageing or stoppage of growth. In the Big Trees or Sequoias, which may attain an age of three thousand years, there is a striking absence of senile changes, for it would be rather far-fetched to call the normal change of living sapwood into supporting skeleton an expression of senescence. In asexual reproduction, among both plants and animals, there is often the same evasion of natural death; and while no multicellular animal, however simple in structure, is known to attain to "bodily immortality," some reach a great age. Thus an easy-going sea-anemone may outlive the naturalist who watches it.

It is interesting to find that in man there is considerable diversity in the ageing of the various organs and groups of organs in the body. Thus the alimentary system, including such hard-worked organs as the liver and the respiratory system, which is also open to being directly influenced from without, is likely to break down before

the nervous system, and the heart before the kidneys—severely tried though these often are.

More important, perhaps, are various sets of facts which suggest that natural death is not so intrinsically inevitable as is usually supposed. Thus, minute pieces of tissue, especially embryonic tissue, can be kept alive in a culture for many years—e.g. fragments of the heart of an embryo chick for fifteen years—the main conditions of survival being periodic change of the nutrient medium, a thorough removal of waste products, and an exclusion of microbes. These tissue-culture experiments, notably those of Carrel, have to be correlated with various other facts: (*a*) the long life of many organisms—e.g. centenarian tortoises and parrots; (*b*) the absence of any detectable senescence in many wild animals of great age—e.g. fishes (whose longevity can be read from their scales); (*c*) the evasion of natural death by most unicellulars; and (*d*) the “device” by which various types of animal—e.g. among Ascidians, Bryozoa, and Zoophytes—undergo de-differentiation or tissue-scraping, and then re-differentiation or reconstruction, with a new lease of life.

Even for a higher animal we can imagine physiological arrangements capable of counteracting the usually imperfect recuperation of wear-and-tear effects. There is no convincing evidence that the living matter as such becomes worn out or fatigued: the arrears are rather in the furnishings of the living laboratory—that is to say, in the less living or even non-living microscopic intricacies of structure which division of labour involves.

Why is a complex organism sure to die, even if it escapes all forms of violence and all the many microbes? The general answer must be: Because of the structural fatigue-effects which the specialized division of labour entails. But when we ask whether this natural death is intrinsically inevitable, our answer at present must be

the recognition of an "unsolved problem." Even in man's case it is conceivable that the accumulation of lethal fatigue-effects might be evaded for greatly prolonged periods. Rejuvenescence *might* be more perfect.

This leads our thoughts to another aspect of the problem: Can there be any advantage to the species in the very general occurrence of violent death, and in the occurrence of natural death if the other forms of the "abhorred shears" are escaped? It is a strange question, but not a foolish one: Can there be survival value in the more or less narrowly restricted duration of life? Is there specific advantage in relatively youthful reproduction and parentage? Even if the physiological taxes on sex and parentage be evaded, multiplication by post-mature organisms is not likely to be for the welfare of the species. Thus we come back to Goethe's insight: "Death is Nature's expert device for ensuring abundance of life."

PART II

PROBLEMS OF NATURAL HISTORY

There is no counting the unsolved problems of Natural History. It would be readily possible to fill many pages with a statement of those of which we are vividly aware, and how many there must be that we have not knocked against! But our present purpose is not to recount, but to arrange these problems. How can they be grouped? One sees at once that they might be arranged in four main groups, in attempted answer to the four great zoological questions: (1) What is this animal, as a whole and in its parts, to the naked eye and under additional lenses? (2) How does this creature work, as a whole and in its organs, tissues, and cells; what is "the go" of it, as Clerk Maxwell used to say, and how does it keep a-going? (3) Whence came this organism, as an individual, how was it minted and coined out of the egg, to use Harvey's phrase; what is its development? (4) How did it come to be as it is to-day, the long result of time; what is its pedigree, and what are the factors in its evolution? All the unsolved problems of Natural History and of Biology must come under these headings: What? How? Whence? And then a deeper retrospective How? But this grouping is too formal, and it does not bring out the varying difficulty of different kinds of problems.

At the outset we may leave aside the series of conundrums which are involved in the central fact of the web of life. They cease to be problems in proportion as we are able to envisage the system of linkages binding one living creature to its neighbours. Thus, what is the connection between cats and clover, between cats and

plague, between water-wagtails and sheep-farming, between squirrels and the harvest, between sunshine and the catch of mackerel, between water-snails and our soldiers in Egypt, between mistletoe and the missel-thrush, between little fishes and the glory that was Greece? These are easy chess-problems in Natural History, and we pass them by.

Then there are unsolved problems of a *quantitative* sort that are sure to be solved some day soon, since others like them have been solved already. Thus, it is almost certain that the mysterious malady known as foot-and-mouth disease is due to a micro-organism, so minute that it can pass through a filter that excludes ordinary bacteria. So far as we know, the investigators who claim to have isolated the foot-and-mouth disease microbe have not quite convinced their critics; but it seems in every degree probable that the organism causing this very costly and lamentable disease will be discovered soon. The organism behind some other "filterable viruses" has been isolated, and so it will be with foot-and-mouth disease. What Dr. Gye and Mr. Barnard have done in connection with a cancerous micro-organism shows how refined methods may solve long-standing problems.

In using the term "quantitative" problem, we do not mean to suggest that the solution is necessarily easy. That depends on the kind of problem. When one has learned to work out the structure of one kind of eye or ear, it is only a question of time to describe all eyes or ears; but experience shows that discovering the life-history of one parasite does not necessarily lead to reading the riddle of another. Similarly, while the nature of many very intricate organic substances has been cleared up, and that of others, at present obscure, will soon follow, there have been no full answers to the questions: What

is the nature of a "vitamin"? Is a vitamin a substance by itself, and if so, what? Or is it some chemico-physical condition of a substance? What, again, is the biochemistry of a hormone, even of adrenalin and thyroxin that can be built up artificially by the synthetic chemist?

In regard to many biological problems it must be said that, while they are in process of solution, the keystone of the arch has not yet been fitted in. We have not got the whole picture. Thus, in regard to the most important chemico-physical process in the world—the photo-synthesis that builds up carbon compounds in the green leaf—we know a great deal, yet far from enough. We know, for instance, that apart from living matter altogether it is possible to use light to bring about the synthesis of formaldehyde out of carbon dioxide and water; and formaldehyde is very probably the first of the organic substances, before sugar and starch and better things, that are built up in the laboratory of the living leaf. Yet no one has yet achieved a complete analysis of what happens in every green leaf on every sunny day.

Incomplete yet progressive analysis, that is the state of many of our unsolved biological problems to-day. How much, for instance, is known in regard to the contraction of muscle? The bathing of the microscopic threads in the liberated lactic acid evokes surface phenomena which make the fibre shorter and broader; and part of the liberated lactic acid is oxidized to supply energy sufficient to reintroduce the rest of the lactic acid or its chemical antecedent into the muscle fibre so that contraction may occur again. Much is known about muscle; there is progress every year; and yet the winking of an eye remains an unsolved problem.

Ignoramus is a word often on the lips of the student of science; but he should never be heard to say Ignorabimus. It is possible, however, that he may sometimes be

attempting the impossible. There may be something asymptotic in the analytic description of a vital process in terms of chemistry and physics; for it may be that in the origin of living organisms there emerged an aspect of reality which the methods of chemistry and physics cannot measure. Thus some biologists do not feel sure that the origin of new departures or variations is a soluble problem in terms of biological categories that leave out "mind." We do not know, but it is possible that some kinds of variations or mutations are in part phenomena that involve expression of mind, and are thus incompletely describable in terms of pure physiology, if there is such a thing. Yet our present point is that while a certain kind of unsolved problem remains unsolved because of incomplete analysis, which we look forward to seeing completed, there are others which may be remaining unsolved because we are seeking a solution by methods which are logically impossible—trying to catch a kind of fish with a net whose mesh is too wide for capture.

No doubt we must continue inquiring into the chemistry and physics of the amoeba's movement, even if we suspect that the secret is beyond these sciences. No doubt we must continue inquiring into the biology of mutations, even if we suspect that the secret of some of them is beyond purely biological formulation. No doubt, again, we must continue studying animal behaviour, with its fascinating intricacies and gradations, its warp and woof of "biosis" and "psychosis," though we may be suspecting all the time that the relation of "body" to "mind" is a limit problem for human intelligence as we know it. Never, however, can we breathe "Ignorabimus"; and to be loyal to science means continuing the endeavour to describe everything in terms of the Lowest Common Denominators that will fit.

There is another kind of natural-history question which enquires into the vital significance of this or that occurrence. "Why are there wasps?" some people say. "Why are there snakes?" say others; but these questions are illegitimate within the domain of science, which has nothing whatever to do with the problem of the big significance of this or that in the purpose of the Universe. And yet it is quite legitimate to *ask* what part wasps and snakes play in the system of Animate Nature as we know it in the here and now. Why are there wasps and snakes? is not a fair question, yet these creatures are threads in the web of life. They have their share in the "Balance of Nature." Thus, wasps destroy many insects and snakes many rodents, checking the multiplication of these prolific types.

By an unsolved problem in Natural History we mean a set of facts that cannot at present be brought into line, that cannot be included in a law or formula. This does not mean that the facts are more mysterious than other facts—for the ultimate mysteriousness of Nature remains all round—it means that we have not got hold of the clue that makes them relatively intelligible. For it must be remembered that science gives shorthand descriptive formulæ rather than explanations of things that happen. It knows only a little about essences and origins. It works with "counters," like "matter," "energy," "protoplasm," "mind," that are all big with mystery. Let us now give a few further illustrations of concrete unread riddles.

We see the dry seeds in bags in the seedman's shop, and we are so familiar with their latent life that we have ceased to wonder, if, indeed, we ever began. Yet here is a riddle all unread. These seeds are not dead but living, as they will show when they are sown. They may remain latent for four-score years, though stories of the sprouting

of "mummy wheat" are quite untrue. Some small animals can remain dry for years; we can hardly call them living, and yet they are not dead. This is true of some Wheel-Animalcules, water-fleas, water-bears, vinegar-eels. What we do not understand is the state of the living matter. Has it stopped changing, or is it going on very slowly, like a smouldering fire? Is the stream of life stagnant, or is it flowing imperceptibly like a glacier?

The all-too-familiar stinging hairs of the common nettle were investigated by Dr. Leonard Dobbin, who proved that they contain free formic acid, which is part, at least, of the poison that ants, bees, and wasps inject when they sting. It is easy to show that the stinging hair of a nettle is a prolongation of a skin-cell of the leaf; it has lime in its walls and flint at the tip, so that it is extremely brittle. When the point touches our skin gently it breaks off and the sharp hair is pushed in, discharging its content of formic acid.

When stinging hairs are made to discharge their contents on blue litmus paper, intensely red spots are produced. This is chemical evidence that what is inside the stinging hair is an acid. When the spotted paper is exposed to air, the red marks are scarcely distinguishable after a few days. This behaviour indicates that the acid is a volatile acid. Dr. Dobbin supplied precise chemical evidence that the volatile acid is formic acid. This has been suspected for a long time, but he has proved it. The chemist warns us, however, not to conclude too hastily that it is the injected formic acid that causes the familiar irritation when we are stung by a nettle.

It has been scientifically shown, indeed, that when the contents of a stinging hair are allowed to become quite dry on the point of a needle, which would allow the volatile formic acid to pass away into the air, the pricking

of the skin with the dry needle produces the stinging sensation and a reddening of the spot. This suggests that there must be something in the hair besides formic acid. Besides, the quantity of formic acid inside the nettle's hair is very small, and seems hardly sufficient for the consequences of the stinging. It is not unlikely, therefore, that along with the formic acid there may be some stronger poison, perhaps of the nature of a ferment.

Everyone knows that the firm grasping of a nettle-leaf bends the hairs flat without allowing the tips to enter the skin, so that we are not stung; but one would like to know more about what seems to be a fact—for some people at least—that holding the breath tightly alters the surface of the skin in such a way that it is not stung, as usual, by gentle touches.

What is manna? The first part of the answer is that manna is not one thing but many. The second part of the answer is that all green plants are sugar-factories, and that manna represents some exudation of sugary substance which has been built up in the normal photosynthesis. Thus, most modern manna (manitol) is obtained by making cuts on a kind of ash-tree, but similar exudations (though without manitol proper) are obtained from many different kinds of plants, such as various species of oak, willow, and eucalyptus. But the third part of the answer is that the co-operation of an insect is often required. Thus, the sugary drops from the Tamarisk shrub, which solidify on the ground on cold mornings, are due to the punctures of a *Coccus* insect. This is probably the manna of the Old Testament.

Other insects besides *Coccus* insects may be concerned in manna-making; thus, Professor F. P. Worley of Auckland has recently described a Manuka manna produced by a sap-sucking plant-hopper; and in another New

Zealand case the exudation came from branches bored by the grub of a longhorn beetle. It came out as a viscous syrup thicker than honey and crystallized into a fairly hard white mass.

When one of the common crabs on the seashore has its leg bruised by a dislodged stone—a common accident—it throws it off from the base by violently contracting two sets of muscles. The leg is always broken off along a particular line—the breakage plane—and inside this there is a membrane of two flaps which folds over the wound and prevents bleeding. A scar is formed, and within the shelter of this a new leg is built up in miniature, to be jerked out at the next moult, thus replacing the one that was hopelessly bruised. Here we have to face the difficulty of thinking out the way by which the prearrangements for separating the damaged leg can have been wrought out in the course of the history of the crab race. There is the surgical puzzle of amputating and bandaging at the same moment. And there is the riddle of “regeneration,” as it is called, the making of a new part to take the place of one that has been lost. A common event bristles with riddles.

Similarly, when a lizard is seized by its tail it often escapes by surrendering the terminal part. The amputation is due to very forcible contraction of muscles, and there is a prearranged weak plane which goes right through the backbone in the tail region. Then there is the gradual regrowth of a new tail, which is usually a bit of a make-shift, hardly up to pattern.

These two cases refer to animals with fairly good brains, but the same device of “a limb for a life” is found at much lower levels, where it seems almost more puzzling. When a starfish has one of its five arms seized by an enemy, or pinned down by a stone, it often escapes by

surrendering the seized or pinned-down arm. There is no special preparation; there is simply a very forcible contraction of muscles at the base of the arm. This is in itself not quite intelligible, but the puzzle we are thinking of is the simplicity of the animal's nervous system. It has no brain; it has not even a single ganglion or nerve-centre. And yet, like the well-equipped crab and lizard, it has somehow learned, in the course of ages, that it is better that one member should perish than that the whole life should be lost. The crown of it is that the life-saving self-mutilation is followed by a regrowth of the surrendered part. And the appropriateness of the regrowth is often very striking.

We have had the mixed pleasure of listening to three rattlesnakes working their strange instruments. When they vibrate their tails slowly, the sound produced by the rattle is a sort of sharp "clicking," but as the rapidity increases the sound becomes more like a shrill whistle. When the motion is so rapid that the eye cannot follow it at all, the sound is a "whirr." It has been likened to the sizzling of meat frying. The instrument consists of a number of horny bells fitting neatly into one another. If there has been no injury to the rattle, the outermost bell is the original horny tip of the tail; the other rings, or bells, are added on at successive moults, the youngest one being, of course, nearest the end of the living tail. The rattle is a not-living instrument formed at successive moults, and it has sometimes ten or even twelve bells. From the number of bells the snake's age cannot be reckoned, as is often asserted, for three bells may be added in one year. Moreover, it often happens that several bells are broken off by accident. A three-year-old rattlesnake may have nine bells or rings, and a six-year-old specimen may have the same number.

When a dog is pleasantly excited it wags its tail; the motion is an expression of an emotion. Why does the rattlesnake rattle? The shrill noise warns animals to get out of the way, and it has been suggested that this saves the rattlesnake from wasting its venom and perhaps breaking a fang on some creature much too big to be swallowed. According to Dr. Hornaday, the rattlesnake is of a timid and retiring disposition, and rattles its instrument to save itself from molestation. If it be the rule, as is stated, that the rattlesnake does not rattle when it discovers a mouse, which it *can* utilize for food, this would favour the idea that the rattling is an expression of nervous excitement, useful in warning off large animals. It is suppressed when a little rodent comes on the scene, for the timid rattlesnake is not afraid of a silly mouse! But there is an unsatisfactory vagueness in these statements, and the case illustrates what we mean by natural-history puzzles.

When we are dealing with chemical and physical occurrences, such as the weathering of a rock or a shower of hail, our only question is "How?"; but when we are dealing with living creatures we must ask not only, "How does this happen?" we are bound to ask, "Has this any meaning in the life of the animal or plant?" When we cannot give more than a fumbling answer, we say, "This is a puzzle." Let us illustrate these puzzles.

Many of us have wondered at a sedate cat "playing" with a mouse, and sometimes continuing its make-believe, losing and recapturing, after the mouse is dead. This behaviour has been interpreted as a cruel delight in torture, but this is an absurd reading of the man into the beast. It has been interpreted as the cat's way of stimulating its appetite, or of improving the flavour of the mouse; but this is far too subtle, and the cat often leaves its victim uneaten. What does this behaviour mean?

In all probability the way to look at the puzzle is this. A kitten has a strong playing instinct; it plays at catching and re-catching a withered leaf or a ball of worsted; this pays, for it is an irresponsible apprenticeship to the serious business of life, which is catching mice. When the playful kitten is about two months old the sight of a mouse suddenly pulls the trigger of the definite "mousing" instinct. It behaves in a precise way, arching up its back, stiffening its tail, showing its teeth, sheathing and un-sheathing its claws; and then it suddenly leaps and catches the mouse by the back of the neck. The capacity for fit and proper "mousing" is inborn, but it requires to be liberated by actual experience of mice; and if there be no mice the "mousing" instinct may remain unawakened. So much so, indeed, that a mouse has been seen sitting quietly on the back of a cat that did not get its proper mouse-experience at the proper time. The tactics of "mousing" form part of the inborn instinctive repertory, and do not require to be learned; but the play helps to develop the necessary expertness and alertness of movement, and may be called the young form of work. We see, then, that playing has a strong grip of many animals, and the meaning of the sedate cat's puzzling behaviour with the mouse is simply this, that the cat is relapsing into play. The same happens, though less picturesquely, with several other mammals. Its finest illustration is in the otter, which has been called "the playsomest of all animals."

When the winter is over the Mountain Hares put on their summer dress of brown. We see some quaint betwixt and between colours. All through the cold months these Mountain Hares or Variable Hares, first cousins of the Common Brown Hares, have been as white as the surrounding snow. They have been white except the black tips of their ears, just as their enemies, the ermine, have been

white save in the black tip of the tail. As the white hares are changing in spring into a brown suit, a new crop of pigmented fur, so the white ermine are changing into chestnut-brown stoats. We know what happened in autumn to the Mountain Hares, which had been brown all summer. They shed some of their fur, and the replacing hairs were without pigment. There were gas-bubbles, like foam, where the brown pigment lay in the summer suit. Moreover, some individual brown hairs—one has to be careful about the spelling—lost their pigment through the activity of wandering amoeboid cells—Metchnikoff's "chromophages"—which carried away pigment granules from the hair into the skin. The same thing happens when a man's hair turns rapidly white. But the puzzle is as to the *use* of the winter blanching. Does it give the Mountain Hare a garment of invisibility against the background of snow? There may be something in this idea, but it must be noted that the more snow there is on the mountains, the more do the hares tend to leave the heights where they cannot unearth any food. They come down to lower elevations where their very whiteness makes them conspicuous on a green, grey, or brown background. Moreover, we cannot forget that while the hare's winter whiteness may hide it among the snow from the hungry eyes of the Golden Eagle, the same blanching of the stoat will enable it—as ermine—to steal upon the hare. It is to be suspected, therefore, that the chief meaning of the whiteness is not in affording concealment, but in being for a warm-blooded animal the kind of dress that conserves better than any other colour the precious heat of the body in very cold surroundings.

About the month of April the antlers drop from the heads of the Red Deer. There has been a long and gradual preparation for the shedding—an eating away of the bone at the base of the stately growth. What puzzles one

is that there should be an *annual loss* of the antlers, to the making of which so much fine material of bone and blood and skin has gone. It is a costly business building up a fine set of antlers; and yet they are lost each spring. The stag has to begin at the beginning again. But the puzzle grows when we enquire into the use of the antlers. Except in the reindeer, where the hinds have antlers as well as the stags, these remarkable structures are masculine ornaments, like the enormous "horn" or tusk of the male narwhal or unicorn whale, which may be as long as a man is high—the hugest tooth in the world. But the use of antlers is anything but clear. They are far from being very effective weapons; and they often interlock dangerously. Rival stags often box with their forefeet or bite at one another. Moreover, a stag without antlers does not always fail to secure a good following of wives. Thus, the use of antlers is almost as much of a puzzle as the use of the narwhal's "horn." Perhaps in both cases we have to do with exuberant masculine decorations, like the lion's mane or the peacock's tail.

On the dry sloping banks by the roadsides in many parts of the country we often find, in the summer months, a number of holes about the thickness of a lead pencil. If we watch these, we see that they are visited by small burrowing wasps, and if we continue watching we may observe that the wasps carry minute caterpillars into the tunnels. Details differ according to the kind, but the general fact is that the mother-wasp makes a shaft in the bank and lays an egg there, or several eggs. Beside the egg, in the recesses of the shaft, she deposits a small caterpillar or the like, which she has paralysed by stinging its nervous system. This provender—neither dead nor recoverably living—remains as fresh meat for the wasp-grub when it emerges out of the egg. This is admirable parental care, but the puzzle is that the mother dies

before her offspring are hatched. Thus she does not live to see the reward of her labours. She works towards an unseen goal. This is a great puzzle, and we see no way out except to suppose that the routine was established in the racial history very long ago, at a time when the life-history of the burrowing wasps was a little different, when the mothers *did* survive to see the offspring for which they spent themselves. The past lives in the present.

We have chosen a few of the unread riddles and puzzles of Natural History, but we hope it will be understood that there is really no end to them. Whenever one is more or less solved, another crops up. The world becomes more and more intelligible, but there are always peaks beyond peaks. And besides puzzles which will disappear like cloudlets in the light of more facts, and besides half-solved problems, many of the fundamentals are elusive and mysterious. No one understands the true inwardness of sex, or why a cell must divide into two, or how a chick is "minted and coined" out of the egg, or what the kind of activity which we call "living" really means. Long life to the mark of interrogation.

RIDDLES OF THE COUNTRYSIDE

On a holiday in Southern Austria some years ago we stopped for lunch at a simple wayside *Gasthaus*, and while we were waiting, entered into conversation with the friendly girl-waitress who had lately finished her schooling. Among other things, being very ignorant, we asked her the name of the fine river that hurried past. Her eyes became bigger still at our stupid question, and she answered, "Why, it is just the river" ("Es ist halt der Fluss"). Now we knew well enough that hearing the river's name would probably not have made us much wiser, and we did not share the old lady's (it is always an old lady) view that the cleverest thing the astronomers have done has been finding out the names of the stars, yet we could not but feel that the naïve remark: "Why, it is just the river," was symptomatic of a too common human attitude to the familiar. It is not yet easy for the average man to appreciate the significance of the commonplace—for instance, the biological suggestiveness of the countryside, which we wish to illustrate. Just as with the appreciation of beauty, so with scientific interest, it does not usually begin at home.

We must remember that, prodigious as it is, science is still relatively young. It is only some two thousand years since Aristotle laid the foundations of Biology, and apart from a few exceptional enquirers, like Galen, there were few who built on them till the Scientific Renaissance, which we may associate with the date 1543, when Copernicus published his book on the Heliocentric Revolution of the earth and other planets, and Vesalius returned to Aristotelian observation in his book on the structure

of the human body. But even after that dawn, which ended the Dark Ages, the interest in Botany and Zoology was awakened and stimulated, not by the plants and animals at man's door, but by rarities and exotics from other lands or by strange treasures discovered in the sea. To cut a long story short, it was but gradually that even those of enquiring spirit realized that every countryside is a scientific El Dorado, every hedgerow a jungle, every stream an Amazon. First of all, the taxonomists, like Ray and Linnæus, showed that all the problems of classification may be studied within the parish. Then the naturalists whom we now call ecologists, men like Réaumur (pointing on to Fabre), or like Gilbert White (pointing on to Darwin), discovered the fascinating intricacy of the intimate life of everyday creatures. Then the early microscopists revealed a new world of the invisible, that makes the visible more intelligible. Thus one observer, Leeuwenhoek, discovered Infusorians, Bacteria, and spermatozoa. Then the entomologists in particular showed that the deep problems of development were raised by the life-histories of common animals like blue-bottles and butterflies. Huxley proved, perhaps too convincingly, that all the discipline of biological analysis—from organism to organs, from organs to tissues, from tissues to cells and protoplasm—might be obtained from the study of familiar types, like yeast-plant and amœba, bean-plant and frog.

It is a commonplace nowadays, but it took a long time for naturalists to realize that all the problems of anatomy and physiology and the other sub-sciences are abundantly illustrated at our doors, though everyone must admit that the sea has a manifold biological suggestiveness unparalleled on land, and that there are lessons from the Tropics that cannot be readily learned in temperate countries.

For some kinds of biological study it may be said that stay-at-home conditions are best, as may be illustrated by Fabre's observations of the intimate life of the insects of an apparently unpromising corner, or by Miall's investigations of common water-insects, or by Trembley's story of the freshwater Hydra, or by Gilbert White's appreciation of earthworms, or by Tregarthen's descriptions of the home life of otter and badger, or by Miss Frances Pitt's field natural history—among the finest of its kind.

It is undesirable to exaggerate a point like this, for how impoverished our Zoology would be without Peripatus and the King-Crab, without the Pearly Nautilus and the Lancelet, and so on in many directions, but it will be generally agreed that for the study of habits and inter-relations (ecology) and for the study of life-histories (embryology) there are unsurpassed opportunities in the countryside around us, including, of course, the streams and lakes of the particular locality. How much Darwin got out of by no means unusual hedgerows (with their climbing plants), meadows (with their bee-visited orchises), marshes (with their sundews), grass-fields (with their earthworms), and copses with their struggle for existence!

What we wish to do is to illustrate, from common riddles of the countryside, that even the deep problems of Biology are there to be studied.

The problem of gossamer was more than half solved by a boy of fourteen—Jonathan Edwards, who afterwards wrote the famous *Freedom of the Will*. On a breezy morning, especially in autumn, small light-loving spiders of several species are in the habit of ascending gateposts and tall herbs, obeying an inborn negative geotropism. They stand with their heads to the wind and pay out threads of silk, usually, we believe, four in number in British

spiders. As these become longer the wind tugs at them; with a vault the spinner lets go and turns upside down; it is supported by its silken parachutes and carried far afield. It is credited with adding to the length of the threads if the wind falls, and of furling its sail if the breeze becomes too strong. Eventually, and partly by coiling up the threads, hundreds of the aeronauts sink to the earth, and the fields and hedgerows, links and meadows, are covered with gossamer. Now we have to link this interesting custom with the spider's instinctive paying out of a drag-line in critical situations and also to the tropism of climbing upwards. We have to connect it with Blackwall's neat observation that spiders imprisoned on a plant in a moat-surrounded flower-pot made their escape by this sort of ballooning, but never made the gossamer threads unless there were appreciable air-currents in the room—this stimulus being apparently necessary to activate the instinct. So far clear, but there is need for repeated critical observations, and other questions arise. Thus: What do the gossamer spiders gain by their passive migration? Why do hundreds and thousands balloon on the same morning?

Let us take a very different kind of puzzle. Colour vision implies that an animal can discriminate between different wave-lengths of light, and it seems to depend on the differential sensitiveness of the delicate elements called "cones" that share in the structure of the retina at the back of the eye. The colour of an object depends on the way in which the light that falls on it or passes through it is affected. Thus, if the red wave-lengths are absorbed, the object will appear green; if the blue rays are filtered out, so to speak, the object will appear orange. The discrimination of particular wave-lengths of light must not be mixed up with the power of dis-

tinguishing different degrees of brilliance—the intensity of the reflection or transmission. An animal may react to the brilliance of a flower without being able to distinguish its colour as colour. It may react equally to two objects of different colour that have the same brilliance.

Colour-blindness is due to the absence of some substance or some sensitiveness in the retina-and-brain arrangements; it remains in part a scientific riddle. It occurs in man in varying degrees; thus some people can distinguish two colours, others four, and others none. Very common is the inability to distinguish between red and green.

Similarly among animals there seems to be great diversity in the degree of colour-discrimination, and it is desirable to have increased information on these different susceptibilities, for they help us to understand the creature's everyday life. It has been satisfactorily proved that honey-bees (and some other insects) can distinguish and remember colours, and this is important in relation to their visits to coloured flowers, though the olfactory cues are more important. Most vertebrates have some power of colour-discrimination, but there are probably many degrees of colour-blindness. These are inferred from peculiarities in the cones of the retina, and from experiments with food of different colours.

If hens are given a mixture of grey grains and blue grains they are said to ignore the blue ones—at least till all the others have been picked up. This may mean that they do not readily see blue, or that they are attracted by grey. Most diurnal birds are said to be *relatively* colour-blind to blues, and most nocturnal birds are said to be relatively colour-blind to reds, as is concluded partly from feeding experiments and partly from the abundance of brightly coloured oil-globules in the cones in the retina

—oil-globules supposed to interfere with colour-discrimination.

If this conclusion is substantiated, it is not only of physiological interest, but of biological importance, for the Darwinian theory of Sexual Selection will be weakened if it can be shown that the female birds are indifferent, for instance, to the male's decorative blueness.

Many of us will probably remember the story of Madame Theophile, a clever cat which was cherished by the French poet Gautier. According to the story, the poet had bought a green parrot, which he set free on the floor of the breakfast-room. The cat came in, and seeing the new-comer said to herself: "Why, this must be a chicken, a green chicken to be sure, but none the less a chicken and therefore good to eat." But as she sprang at the parrot she was met by the question, "Have you had your breakfast?" The cat fell back, her thoughts were apparent: "This is not a bird; it speaks; it is a gentleman." Now one should not too scientifically criticize good stories of this type, but the question rises whether cats can distinguish colour at all. The evidence is strong that all cats are colour-blind; but is this quite certain? And what about other creatures?

We are often asked whether adult salmon ever feed in fresh water. When the question refers to the European Salmon (*Salmo salar*), the answer should be "hardly ever."

It is in the sea that the salmon feeds (on other fishes like herring, and on crustaceans like prawns); in fresh water the salmon fasts. The stomach is always empty and the intestine shows no débris of food. Moreover, the lining of the alimentary canal as a whole is rather out of gear, as far as digestion and absorption are concerned. The reserves stored up in the sea supply the energy expended in ascending the stream and are also

utilized in the ripening of the reproductive organs. Some anglers believe that the "kelts"—i.e. salmon spent after spawning—devour other fishes, including their kith and kin; but there is very little precise evidence of this. Of course the young stages, like parr and smolts, eat largely; our question refers to the adult salmon.

But if adult salmon do not eat in fresh water, how is it that they take artificial "flies" and "minnows" and other lures? Perhaps the answer is that they are like children who have no appetite for their porridge, but cannot resist a bit of bacon. Perhaps they are like the fasting friar who easily resists the crust of bread but casts longing eyes on the savoury pasty. In many living creatures there is a sharp contrast between a nutritive and a reproductive period, and it is so in the salmon. The body is unappetised during the reproductive period, but it is not unintelligible that an unusual and unexpected stimulus, such as "fly" or "minnow," should pull the trigger of the gulping instinct *irresistibly*.

Why are spiders not snared on their own webs? The threads of a spider's web glisten with drops of a viscid secretion which entangle the legs and wings of insects. Why is the spider not itself snared when it runs across its web? Fabre gave the answer, which others have confirmed, that the hairs on the spider's body and legs are oiled, and this oil prevents adhesion. The spider may be seen spreading this oily secretion on its body, and this is part of its normal toilet. Somewhat similar is the varnishing of the hairs of the Water-Spider, which do not become wet in spite of the aquatic life.

Why don't we hear Nightingales during the day? Because we are not listening for them or because their song is drowned by that of other birds, such as thrushes

and blackbirds. A nightingale may be heard at noon; he may be seen on a hedge or bush singing for all he is worth—and that is much. Mr. Coward says in his excellent *Birds of the British Isles*: “During song the tail quivers; indeed the whole bird shivers with energy; it sings with its body, like the Wood-Wren.” It is safe to say that the nightingale is more voluble after dark than other birds are, but it is not by any means the only serenader.

How is it that heathers succeed well on the unready soil of the moor where few plants flourish? According to Miss Rayner and others, the heather does well on difficult situations like the sides of the mountains and some kinds of sand dunes because it is in partnership with a fungus which penetrates it through and through—from root to shoot, from leaf to flower, and thence to seed. This conclusion has still to meet some criticisms, and it requires to be deepened by a discovery of the precise way in which the partnership works—possibly by enabling the dual plant to capture the free atmospheric nitrogen, e.g. in the soil-air and soil-water; but the reality of the symbiosis seems to be well established. It may be compared to the partnership between root-fungi and many trees, e.g. Conifers, and to the symbiosis of Bacteria and Leguminous plants on which they form root-tubercles. These symbiotic bacteria are somehow able to capture the free nitrogen in the soil.

Why does a bat sometimes tumble in mid-air? When we watch almost any of the smaller British bats hawking insects in the twilight, we may see it tumble for a couple of feet in mid-air, and then recover itself. What is the meaning of this “fall”? The answer has been given by Miss Frances Pitt, who points out that when a bat has caught an insect—say a high-flying beetle—and is holding

it half-killed in its mouth, the next step is to give it a lethal bite. But if it opens its jaws to give a second bite the booty may readily escape. So the bat bends its head downwards and backwards and presses the insect against the "inter-femoral membrane," a triangular fold of skin, which extends in most small bats between the thighs and is supported in the middle line by the tail. By pressing the insect against this membrane the bat can give the fatal bite without risk of losing what it has captured. While it is preoccupied in this action it not unnaturally sinks a few feet in the air. This is the explanation of the bat's familiar "tumble." In some cases the flexible membrane is used as a little skin-bag for carrying booty.

Why are earthworms ranked as the most useful of all animals? The reason is that they have made most of the fertile soil of the globe. As Gilbert White discerned and as Darwin demonstrated, earthworms are of fundamental agricultural importance, (*a*) in burrowing, their holes making way for plant-roots and rain-drops, and promoting soil-aëration; (*b*) in bruising the soil in their mill-like gizzards, and thus making new surfaces on which solution and other processes occur; and (*c*) in burying the surface with their castings and in burying leaves, which, if they decay, help to form vegetable mould. There are many different kinds of earthworms, occurring over most of the world excepting very dry places, very wet places, salt soil, and much frozen land. Darwin found that there are 50,000 individuals per acre of arable ground in Britain, that these pass through their food-canal ten tons of soil per acre per annum; and that they bury the surface with their castings at the rate of three inches in fifteen years. Truly the great soil-makers of the world!

In 1777, Gilbert White wrote his famous letter on earth-

worms, one of the best illustrations of the harvest of a countryman's patient eye. We should go back to that remarkable letter to appreciate afresh its thoroughness, for in his picture of the work of earthworms Gilbert White anticipated most of the points which Darwin, with his supreme carefulness, proved up to the hilt. In his terse and prescient letter, Gilbert White said that "a good monograph on worms would afford much entertainment and information at the same time, and would open a large and new field in natural history," and none of us who have made our pilgrimage to the Down House can have missed the thrill of seeing on the lawn the flat stone which Darwin used in his famous experiments which proved that earthworms are the most practically useful animals in the whole world. In his letter of 1777, Gilbert White said: "These hints we think proper to throw out, in order to set the inquisitive and discerning at work," and Darwin's ecological masterpiece was published in 1881, the year before he died, the outcome of over forty years of observation, begun when he was a truant student of medicine in Edinburgh University.

Now we must be clear that in spite of the perfection of Darwin's study of earthworms, there is still room for "the inquisitive and discerning" to keep working. Some years ago we noticed thirteen long tough midribs, radiating like the spokes of a wheel, round the mouth of an earthworm's burrow. They were too tough to be of use and had been left outside, while their leaflets had been buried. A glance round showed that the midribs belonged to a Mountain Ash or Rowan-tree, growing close by; and as each leaf has seven leaflets, there had evidently been a burial of ninety-one, some of which were readily visible. Now there was nothing novel or startling here, but the fact that ninety-one leaflets had been taken in a short time into one burrow would have pleased Darwin, and

was, as it were, a picturesque postscript to his great book on *The Formation of Vegetable Mould by the Agency of Earthworms*.

Similar, but of greater importance, is the fact, which many must have noticed, that earthworms take irrelevant objects, such as pieces of string and entire feathers, into their holes. These are possibly of use in making the burrows more comfortable, but the interest of the observations is in showing that it is *instinctive* on the earthworms' part to grip objects that are superficially like leaf-stalks. They do not exhibit *intelligent* selection, and yet the question arises why they should leave midribs on the surface, while taking somewhat stiff feathers underground. More observations are needed.

Earthworms have been kept in a Y-shaped tube so arranged that if they climb up through one of the arms of the Y they reach a pleasant surface, while if they try the other they find themselves in a blind alley with a mild electric shock. They soon learn the lesson, profiting by experience. But headless earthworms are almost as quick in "learning" to keep to the right side, so that we are warned once more, as Spinoza said, that we must not be too sure what the body as body may not learn.

How is it that partridges and some other close-sitting birds are practically devoid of their usual odour when they are brooding? Birds have no sweat glands, as mammals have, and no odoriferous glands, such as are frequent among mammals, as in musk-deer and skunk; the superficial glands of birds are represented solely by the oil-gland at the root of the tail, which helps in the preening of the feathers, and by occasional small glands near the ear-aperture. Yet many birds have a distinct odour, which must come either from the food-canal or from the general surface of the skin. The question is why this is practically

absent during the brooding of some close-sitting birds like the partridge. A dog may pass close by the partridge's nest in the hedgerow without noticing the well-camouflaged bird. The riddle of the so-called "suppression of scent" has not been satisfactorily solved. It may be that the birds are eating very little during the brooding period, that the waste-products are voided at some distance from the nest, that the feathers are kept closely appressed on the skin, and that the preen gland is not so active as usual. This illustrates the kind of riddle that a few careful observations might readily solve, but, so far as we know, these are not as yet forthcoming.

Why do horses occasionally shy? There is some unusual rustle among the long grass by the side of the road, and even the well-trained and docile horse makes a sudden swerve, almost capsizing the gig or making the rider lose his seat. The horse "shies," but what does this mean? It is probably a reflex action, that is to say (as explained elsewhere) that there is a pre-arranged linkage between (*a*) sensory nerve-cells which receive tidings and pass them by sensory nerve-fibres inwards to (*b*) associative or connecting nerve-cells; these receive the impulse and pass it on to (*c*) motor nerve-cells whence, by motor nerve-fibres, orders pass to certain muscles, which contract. It is not such a simple reflex action as withdrawing our finger from a hot cinder, for the horse sees some movement or hears some rustling, and the message travels to the brain, whereas for a simple spinal reflex it is enough if the message travels to the spinal cord. It is possible that the sudden movement in the herbage or the abrupt emergence of a stoat's head awakens some mental association in the horse's fine brain; but we do not know. It may be that it is all on the physiological plane and that the quick swerve or

leap is due to the activation of an ancient reflex established in the ancestral horse's body when horses lived as wild animals on the plains, and when it was of life and death importance that there should be an instantaneous rebound from a lurking carnivore that might spring, or from a hidden snake in the grass that might make a lunge, unprofitable to itself, but dangerous to the horse. Thus, shying evolved, and in domesticated horses it has in most cases outlived its utility.

There is a case in the Natural History Museum in South Kensington showing albinos, that is to say, animals born without their natural pigment. Thus, there are white blackbirds, white crows, white swifts, white rabbits, white rats, white mice; and, as the last examples show, it is possible to establish a healthy true-breeding race of these albinos. What happens when an albino suddenly crops up in a pigmented race? In all probability the factors for pigmentation have been lost in the intricate nuclear manoeuvres which occur in the ripening germ-cells. Thus, in the case of an animal with one of the dark pigments or melanins, it seems to be necessary for a ferment (tyrosinase) to act on a pigment-producing substance (tyrosin); and if either factor should drop out of the inheritance, the fertilized egg-cell must develop into an albino. As is well known, the eyes of true albinos are red, because the blood shines through an unpigmented iris.

Probably quite different from what we have just referred to as "true albinism" is a phenomenon which has been noticed several times where a coloured animal suffers depigmentation. An interesting case has been recently described by P. Murisier. It concerned a hen, three years of age, that changed from black to white and also developed masculine characters. The feathers lost

their pigment from the base upwards, and in seven months the hen passed through four stages—uniform black, pied with a white head, white, and finally “isabelline,” which we take to mean sand-coloured. The reproductive organs were normal, but the bird seemed to be suffering from pernicious anæmia, and the post-mortem examination also showed that there were great deposits of pigment (hæmosiderin) in the liver. Thus this “false albinism” would differ from “true albinism” in being acquired rather than inborn, in implying depigmentation rather than non-pigmentation, and in being pathological.

The other day we came across a birch-tree with over two dozen witches'-brooms. It looked as if there were a rookery on a single tree, for everyone admits the likeness of the witches'-broom to an old nest. The tangled mass of twigs is, of course, an abnormality of growth; it is provoked by a number of fungi, mostly of the group called *Exoasci*, which do other things on other trees. The fungi send their threads into the skin of the host plant, like grass roots growing in a shallow way in the ground. It is very usual for the broom to begin in a bud which has been infected by a spore during the previous summer. In some way not clearly understood, but with its analogies in galls and the like, the irritant presence of the fungus provokes the bud to send out numerous weak twigs. In the course of time there is a crowd of these twigs, many of them dead or half dead. Spores are produced on the surface of the leaves of the broom and multiple infection occurs. It is interesting to notice that the leaves of the birch broom, which has been well-called a “bud-tumour,” are much larger than the ordinary leaves of the tree. Thus, the presence of the fungoid threads is rather stimulating than destructive. Another interesting point is that it has been found possible to produce a

witches'-broom on an alder-tree by artificial infection. In many cases in Nature it is probable that the infection begins by spores getting into the wounds made by mites. But the most interesting fact is the one we least understand, that the intruding fungus somehow stimulates the birch-tree's living matter to behave in a disorderly way—recalling abnormal growths in man and animals, except that witches'-brooms are not malignant.

CHAPTER XXVIII

CUCKOO PUZZLES

The world of life bristles with marks of interrogation! One sees them everywhere, and, as we have illustrated in previous chapters, some of the questions have had partial answers—else there were no science at all. That is to say, we know in many cases a good deal about causes—how there is dew on the grass, why bees visit certain flowers more than others, how a ptarmigan turns white in winter, and what is the origin of wool. The usual procedure is that we account for things by referring them back to some general law of which they form a particular application, but sooner or later we land in some “irreducible,” like electricity or protoplasm, that we have to take more or less for granted for the time being. In a strange case like the vagaries of the cuckoo, the puzzles have become much less perplexing as our knowledge of the facts has increased, but we know that our increased clarity is due to our appeal to such deep secrets as variability, individuality, and instinct.

One of the distinctive notes in the merriness of May is the calling of the male cuckoos. As soon as the morning sun has warmed the air a little, the rogue begins to shout, sending his resonant two syllables across the meadows and along the hedgerows and through the copse. Often he is at it before five o'clock in the morning and he is not tired by nine o'clock at night. We wonder how many times he says “cuc-koo” in the course of the day; from our window we have heard over thirty shouts in an hour, and we do not think that more than three male birds were participating. In that hour we counted distinct shouts with every number of “cuc-koo” calls from one to

thirteen, the most frequent number being seven. More prolonged shouts were also heard, such as seventeen and twenty-three. Our record for an uninterrupted shout was seventy "cuc-koos," but although there was no break, it is possible that a rival male cut in unobserved, just when the first one began to get out of breath. The males call to make the females aware of their presence, and to challenge their rivals, and simply because they cannot help it. They shout from a perch or as they fly, and the poet's reference to the "wandering voice" is apt enough, if it be at the same time understood that the shout of one cuckoo may be answered by another a short distance away. We have heard this "echo" both to right and left along the hedgerow, and then a minute afterwards the original shouter answered from between them. It is safe to say that it is usually the male who says "cuc-koo," but we can add nothing to Mr. Coward's cautious statement: "either the female at times says 'cuc-koo,' or the clear, bubbling cry, stated to be hers alone, is shared by the male, *for one bird will make both remarks.*" The sexes are externally indistinguishable.

The major puzzle of the European and many other cuckoos is that the brooding is done by proxy, a peculiarity which is not habitual in any other type except in the unrelated American cowbirds (*Molobrus*), several species of which utilize the nest and kind services of other birds. One species, *Molobrus rufoaxillaris*, makes use of the nest and hospitality of a congener called *Molobrus badius*, which may also be at times dependent on ordinary birds of respectable ways.

Many species of the cuckoo genus (*Cuculus*), and of related genera, have the so-called "parasitic" habit of foisting their eggs on other birds; but there are other kinds, like the two common North American cuckoos (*Coccyzus*), which build nests of their own. Among these

is the strange Californian "Road-Runner," which runs more than it flies, and is often seen hurrying in front of a horse-drawn vehicle, persisting in the habit fatally in modern days of motor-cars. The Ani, another kind of cuckoo in the wide sense, is at the opposite extreme from our cuckoo, for a number of mothers pool their eggs in a common nest and incubate gregariously!

The first contribution to the major cuckoo puzzle is that many birds in a hurry or a flurry drop an egg into the nest of some other kind of bird, where it is sometimes successfully incubated. The second point is that among cuckoos, in the wide sense, the habit is not universal, and is not always equally perfect.

Another consideration that lessens the appearance of bizarre freakishness in the cuckoo's parasitic habit has been elaborated by Professor F. H. Herrick. In brief statement it is this: A typical life-history shows a sequence of chapters, and it is not very unusual to find some disturbance in the succession. Thus the period of animal childhood may be greatly prolonged, just as in mankind; or the breeding season may be greatly lengthened; or parental care may be dropped out altogether; and so forth. The various arcs on life's trajectory may be lengthened out or shortened down, and reasons for this may be found in variations in the activity of the ductless glands, or in the rate of development of the nervous system, or in other deep changes in the constitutional routine. These variations in what may be called the *tempo* of life are familiar amongst ourselves, for some people are born old, while others are boys at the age of threescore years and ten.

Now, as Professor Herrick points out, the normal sequence of events for an ordinary summer visitor to a given country is as follows: (1) arrival, (2) courting, (3) mating, (4) nest-building, (5) egg-laying in the nest,

(6) incubation, (7) care of the young in the nest, (8) nurture and education of the young after they have left the nest, and (9) departure. One term in the series may be weakened and another may be exaggerated; thus a pair of birds may build two or more nests and yet use only one; or they may have two or three families in succession; or they may skip the brooding chapter, as the mound-birds do; and there are other "temporal variations." Herrick's suggestion is that the cuckoo's peculiar habit illustrates a lack of attunement between the egg-laying and the nest-building. This is casual in many birds, but has here become so serious that the nesting is perforce vicarious. As to the origin of the lack of attunement, what can we say at present save that disturbances in the rhythm of a life-history are not uncommon among animals? The disturbances depend on something awry in the regulation of the bodily activities, and this may mean something unusual in the hormone-producing organs or in the nervous equipoise. Behind that we can only say: "Variability."

The cuckoo has made a success of the strange habit of shirking parental duties and securing brooding by proxy; and we have seen that this is not so unique as it seems at first sight, since it is of casual occurrence among many other kinds of birds. But while this is a useful idea so far as it goes, it does not go far enough. We are bound to ask if the cuckoo has other peculiarities which throw any light on the success of its remarkable departure from use and wont; and there are interesting answers. The sagacious Dr. Jenner, who was almost as much interested in cuckoos as in cow-pox, pointed out that the European cuckoo has only a short time to stay in its summer quarters, and much to do in that short time. It usually comes in April and leaves in August, and a striking feature, unique among British birds, is that the parents leave our shores

six weeks or so before their offspring, of which they have no knowledge and have taken no heed. The difference in time will, of course, be less if we compare the *last* departure of the adults with the *first* departure of the youngsters, but the general fact is undoubted—the adults are in a hurry. Part of the explanation is probably that cuckoos are more or less specialists in their diet, depending largely on caterpillars, including the hairy ones; and this kind of food is becoming scarce towards the end of summer. The problem is different for the young cuckoos, for they are fed by their bemused foster-parents even after they leave the nest. Many country-folk have watched the quaint sight of a meadow-pipit or a hedge-sparrow feeding a much larger and highly appetized young cuckoo. The winter quarters of our cuckoos are but vaguely known; autumn arrivals and winter visits have been recorded for Central and Southern Africa and for the Near East.

Another feature that may throw some light on the cuckoo's utilization of the nest and brooding hospitality of other birds is that the egg-laying seems to be spread over a longer period than usual. It is naturally difficult to get secure data, but many ornithologists believe that a mother-cuckoo often lays her eggs at intervals of a day or two, with half a dozen or so in one period; and that she may begin a second laying period after a short rest. If there are intervals of a day or two between the laying of successive eggs, the advantage of putting each egg into a separate nest is obvious. If the cuckoo behaved in the usual way and laid all the eggs of one period in a nest of its own, there would be inconvenient differences in the times of hatching. One of the ways in which expert observers arrive at an estimate of the number of eggs a cuckoo may lay is of interest. There is extraordinary variability in the colouring of cuckoos' eggs, but there is

strong evidence that a particular cuckoo produces only one type. Therefore, if six eggs of a particular colour are found in six nests within a short distance of one another, and if no other instances of that colour can be found in the vicinity, there is presumptive evidence that the six eggs were produced by one and the same bird. But, as we have said, there may be a second period of laying; and some cuckoo experts insist on more. In any case, the fact that there are rather long intervals between the successive layings makes it easier to understand the success of the "parasitic" device. It should be mentioned that the cuckoo's egg is usually larger than those of the foster-parent, and that the texture of the egg-shell is distinctive to the expert "oologist."

But the cuckoo has other peculiarities, and if we knew enough it might be possible to string several or all of these together and see them in correlation. Thus there are far more males than females, with polyandry as a consequence. That is to say, the female accepts and indeed invites several males, none of whom is a habitual mate. The sexual has overshot the parental in those species of cuckoo that have become wholly "parasitic"; and yet it has to be admitted that the mother-bird sometimes shows considerable care in the disposing of her eggs. Two methods have been substantiated. In some cases she lays her egg on the ground, lifts it in her bill, and flies to a more or less suitable nest in which she deposits it. The coloration of the egg is sometimes so like that of the foster-parent's eggs that it is difficult to distinguish them; in other cases the cuckoo's egg is startlingly different. It is not likely, therefore, that the congruity or the incongruity has much significance.

There is no doubt, however, that the mother-bird sometimes *lays* her egg in a selected nest, such as that of a meadow-pipit; and the presence of identifiable egg-

shells in the food-canal of a female cuckoo shot at the laying time corroborates certain observers who have seen the bird making more room in a preoccupied nest. It must be noted, however, that a cuckoo's egg has been found in the nest of a swallow, a reed-warbler, and a tree-creeper, and of some other birds in which it could not be *laid*, though it must have been deposited.

The cuckoo's egg, incubated by the foster-parent, develops rather rapidly, and the newly hatched bird is in most cases big for the nest. It does not lack self-assertiveness, and that is increased by an exaggerated "touchiness," especially on the small of the back, which lasts for about eleven days. When one of the rightful tenants of the nest, if there be any left, touches the young cuckoo's back, it provokes epileptic-like convulsions, the result of which is often the ejection of the young meadow-pipit or whatever the other bird may be. Thus the cuckoo is "a dog in the manger" by birth.

We must think of the cuckoo as a bird in which the nesting and brooding instinct has dropped out of the inheritance, the situation being saved by the evolution of an instinctive routine—still somewhat variable—mingled with some degree of intelligent awareness. But, after all is said, the vagaries of the bird illustrate an imperfectly solved problem—and a fascinating one.

CHAPTER XXIX

THE CAT'S NINE LIVES

Men may be divided into two groups, according as they rank the cat or the dog as the more intelligent animal. This has nothing to do with which of the two one likes best, for that is a question of taste; whereas the relative intelligence of the two types is a problem in comparative psychology. A good deal may be said on both sides, but those of the pro-feline persuasion often do their case harm by citing as instances of intelligence what are really examples of sensory equipment or of bodily fitness. A cat can see in the dark better than a dog can; but it does not follow that a cat has the better brains. A cat can climb a tree, which is not one of the dog's accomplishments; but it does not follow that a cat is more intelligent than a dog. It might indeed be advanced by the pro-canines, as an evidence of the dog's superior intelligence, that it is never up a tree. Be this as it may, we cannot believe that all the nine lives a cat has afford equally convincing demonstration of its wits.

The first of the cat's nine lives is that it always falls on its feet. This is an adaptation that has arisen in connection with, we do not say as the result of, the ancestral habit of climbing trees. In the course of ages those cats that did not fall on their feet have been eliminated. It must be understood, of course, that the cat's way of falling on its feet is but a special case of the balancing or "righting" power which is particularly associated in backboned animals with the semicircular canals of the ear. It was, indeed, the primary function of the ear before it became an auditory organ. Hearing is a secondary luxury superadded to the primary necessity of balancing.

If you lift a friendly puss by its forelimbs and by its hind-limbs, hold it back downwards a yard or so above a quilt, and then let go, the cat will fall on its feet, just as it does when it slips off the top of a wall. If it doesn't, then you have come to possess an over-domesticated cat that has lost one of its lives! Every stage in the cat's normal tumble has been photographed and carefully studied, and it has been proved that by an unvarying succession of reflex movements the falling cat rights itself so that it lands on its spring-like feet.

The cat's second life is in its "whiskers," that is to say, in the exquisite tactility of the richly innervated long hairs or vibrissæ which project from its cheeks. These specialized hairs are common in mammals, the finest being found on the upper lips of some whales, which may be otherwise hairless; but they are highly developed in the cat tribe, and are very useful when the animal touches something in the dark. The third life is in the sense of smell, and the fourth (for we must make headway) is in the sense of hearing. For although it is usual, we think, for a tortoiseshell tom-cat to be stone-deaf, ordinary cats and wild cats are able to hear well. They can distinguish to a nicety between different sounds; they build up associations on a basis of discriminated noises or words; but what they recognize are differences in intensity, not in tone or pitch. Those delightful people who assure us that their particularly intelligent puss "understands every word they say" are the salt of the earth; but they should give up comparative psychology.

The cat's fifth life is in its power of seeing in the dark. Strictly speaking, of course, we cannot say that any animal sees in the dark, but the cat comes near it. That is to say, it is able to utilize the scanty light of dusk and dawn, for almost all members of the cat tribe are nocturnal hunters. The power of seeing in the dark depends in part

on the way in which the muscular iris can contract or expand in glare or shade respectively. As everyone knows, the cat's pupil (the aperture through which the lens is seen) may be like a pin's head in bright illumination, or a large dark circle, as if puss had been using belladonna, when there is deep shade. The full expansion of the cat's pupil enables the eye to make the most of the dim light, and this gives an extra life when prowling about in the darkness.

The cat's retina, or image-forming layer, includes a singularly beautiful mirroring surface or tapetum, and it seems likely that this, by reflecting the scant rays, helps the cat "to see in the dark." It is the reflection from the tapetum that we see when the cat's eyes "shine in the dark" in an almost dark room. No eyes in the ordinary sense are able to produce any light, and the eyes that shine in the dark are simply reflecting what scanty light there is. Even a cat's eyes do not shine in a photographer's dark-room.

Speaking of eyes, we must admit that all cats are colour-blind. They live in a grey world, monotonous as regards colour. You may feel sure that your cat knows at once when you put on your beautiful red dress, but it is necessary to distinguish between colour as colour and brilliance or intensity of reflection from a shiny surface. A dozen careful experiments have shown that cats are not only tone-deaf, but colour-blind; and both defects, if they are defects, may be associated with the custom of hunting at night. We must not think exclusively of our domestic cat, which is probably a derivative of an Egyptian wild species, and apt to be sophisticated in many ways.

The cat's sixth life is in its capacity for homing or for orientation from a distance. This is of importance in natural conditions in the forest or other wild haunts,

for it would never do not to be able to return quickly to the den, especially when there are young ones to be fed.

Let us return to the cat's behaviour in face of a meddlesome dog. Several naturalists of half a century ago went the length of saying that the cat deliberately made itself bigger in the eyes of the dog by willing its fur to stand on end, but we now know that what happens is something very different from willing, or taking thought. Whether the cat is really much afraid is a difficult question, the answer to which, perhaps, depends a good deal on the temperament and experience of the individual cat, but it is probably true that in most cases puss is on the border-line of fear, and that in all cases she is considerably excited. Our question now is as to the bodily side of all this.

To answer this question we must remember that inside the cat—as in all other mammals—there is in front of each kidney a small organ called the supra-renal body, which is now known to play a very important part both in everyday life and in extraordinary situations. It is a gland making a secretion called adrenalin; but it is a ductless gland, and the adrenalin it makes is liberated into the blood, not into a cavity, as is the case with the secretion of a digestive gland, which passes into the food-canal, not on to a free surface, as is the case with the secretion of the sweat-glands, which is poured out on the skin. The adrenalin manufactured in the central portion of the supra-renal organ is distributed by the blood through the body, and has extraordinary effects in various parts.

It is one of a set of bodies now called hormones—or stirrers-up—which travel as “chemical messengers” from one part of the body to another, and always promote the welfare of the creature as a whole. Now, an extra production of adrenalin has many effects, such as increasing the

pressure of the blood-stream, the vigour of the heart-beat, the tone of the muscles, and so on; and one of the minor effects is to contract the tiny muscles which raise the hairs. We now begin to see the circle of events. Strong emotion, such as fear, means great activity in the central nervous system; it may be a sort of nerve-storm. The news spreads through the body by the nerves, and the supra-renal body is stimulated to an extra production of adrenalin. This powerful hormone is distributed by the blood to parts both near and distant, the tiny muscles which raise the hairs contract, and the cat's fur stands on end. The whole thing takes place very rapidly; it might almost be called automatic if that word did not suggest a machine, which is not a good term to use when speaking of a living body, especially when emotion comes in.

When we feel very much afraid part of our fear consists in picturing consequences in our mind and in anticipating pain; and it is not likely that there is very much of this among animals. But we dare not be too sure on the subject, especially when we are dealing with creatures endowed with fine brains. We are on surer ground when we recognize that the bodily side of fear is much the same in ourselves as in the cat. Emotion excites an extra flow of adrenalin, and it is the influence of this hormone that makes our hair stand on end, dilates the pupil of our eye, makes us pale with fright, and so on. One of the many interesting things about adrenalin is that it can now be made artificially in the chemical laboratory. It is sold in the druggist's shop, and used to stop nose-bleeding and the like, for making the blood to clot is one of its many potent properties.

If we consider the emotion of anger, or rage, the case is even more striking. When a man comes to know of some act of cruelty, or breach of faith, or false accusation, he experiences righteous anger; or he may get into a rage

because of some trivial insult, or without any good reason at all. If the man's anger is real, the nervous storm associated with the emotion affects the supra-renal bodies and provokes an extra flow of the adrenalin hormone. This is distributed by the blood, and it almost instantaneously brings the body into an excited state, often very well suited for a fight, or a tussle, or some great exertion. The pressure of the blood-stream is therefore increased, and the blood tends to pass from the lower internal regions to the heart, lungs, nervous system, and muscles. The heart beats more vigorously than usual; the amount of sugar in the blood is greatly increased, sometimes by about twenty per cent., which makes it more nourishing to the muscles, and is encouraging to the whole system. The coagulability of the blood is also increased, making it clot more quickly if there should be a wound in the fight. The excitability of the muscles is heightened, and their power of recovery from fatigue is increased, which will make it easier to prolong a hard struggle. There is also an interesting stoppage of the activities that go on in the food-canal. In short, there are elaborate rapid preparations for a fight. The whole body, as Irishmen say, is "spoiling for a fight," and all through the influence of the emotion of anger on the production of that chemical messenger which is called adrenalin.

It is plain enough that in the long-drawn-out struggle for existence among animals, which often, though not necessarily, implies a literal combat, this preparation of the body must be of great value. It is the sort of quality that tends to persist, and to be improved upon. It may be reasonably asked, however, what the function of adrenalin may be in uneventful everyday life, when there is neither fear nor rage. Perhaps the everyday life of wild animals is always rather eventful, but, so far as man is concerned, a sure answer is not forthcoming just now; and when that

is the case it is always better to say so. It is quite possible that adrenalin has only occasional uses, unlike most other hormones, which are continually utilized in the wonderful internal economy of the body.

In regard to these remarkable new discoveries we must be very careful not to hurry to conclusions beyond the facts. It is only in a general way that we know what happens inside the body when a naturally timid man rescues a child from the jaws of death, or when a soldier wins the Victoria Cross. Different constitutions are differently affected, and what happens will depend in part on the kind of life a man has led, and how he has been in the habit of treating his nervous system. Fear sometimes paralyses a man who has it in his heart to be brave, and anger sometimes produces so much internal pain and disturbance that a man can hardly speak or act.

One thing stands out clearly from our recent knowledge of all these things. We know something about the chain of events. It runs something like this:

1. Anger.
2. Stimulation of the supra-renal body.
3. Increased production of adrenalin.
4. Distribution of this chemical messenger through the body.
5. All sorts of effects in the body, such as increased fitness for fighting.
6. The fighting itself.
7. The reaction of the bodily activities on the feelings.

Then, although we dare not assert that righteous anger will increase a man's fighting power more than unjustifiable anger does, we have a shrewd suspicion that this is so. "Thrice is he armed who has his quarrel just."

Such are seven of the cat's nine lives; and as none of them implies intelligence, they must not be cited as evidence on the question whether cats or dogs are the

cleverer. More important, however, is the fact that the cat must have many more than nine lives. For we have not spoken of the maternal devotion, the education of the kittens, the ready-made instinctive impulses, such as chasing a moving object, the self-assured independence and ability to walk alone in all circumstances, the highly evolved body, from teeth to claws, and the first-class intelligence as the crown of all.

CHAPTER XXX

HOMING

A cat, transported by rail from Fife to Ayrshire, did not take to its new quarters, went a-roving in a day or two, and was back at its old home within a week, having traversed the breadth of Scotland with success. From a scientific point of view it is a pity that the cat was not re-transported to Ayrshire, to see whether it could "home" a second time with the same or greater success. And it might have been possible by observation to get some clue to its movements. There are many similar records, interesting but sadly lacking in precision. In one case, where a distance of over thirty miles was retraversed in a day, sceptical enquiry proved that the supposed traveller was another cat of the same name! Moreover, some cats readily lose themselves not far from home, and no one records the failures in orientation. More facts are needed, and they should be critically collected, especially since it is not difficult to make sure that the cat gets no obvious sensory cues on its outgoing journey. The homing power of horses is well known, but in most cases it seems to be explicable in terms of visual cues and registration of movements. It is, of course, very interesting that horses should remember turnings and difficult places as they undoubtedly do, but there is no particular puzzle in the power of registering muscular movements, as man himself often does. Similarly, the dog's ordinary success in finding its way home is largely due to olfactory cues.

As regards the homing of mammals, then, we may say that there are few puzzles except in cases where the outgoing journey was passive, say in a train, and without the possibility of ordinary visual cues, e.g. when the

transport was effected in a closed basket or the like. The best instances of this relate to cats, and in the experiments for short distances, such as two or three miles, there seems to have been an elimination of visual, olfactory, and auditory cues on the outgoing journey. In some cases the transported cat has been chloroformed, and on these occasions the return journey took longer than usual. In some cases the cat, within its travelling-bag, has been taken on a boat for some distance on a lake and turned about in all possible ways, but this did not seem to make any difference to its homing. In some cases, the liberation from under a box was effected by a string from the observer hidden in a tent a hundred feet away. With striking unanimity the experimenters record that the liberated cat behaves like a compass and starts right away in the proper direction. "She did not pause and sniff in varying directions, nor seem to peer first one way and then another, nor run round in circles seeking the proper direction, nor did she ever backtrack over the course followed by the automobile in coming out; she merely turned in the direction of home and started back."

If there are no cues on the outward journey, save the motion of the car; if the return home is fairly rapid, and not due to numerous tentatives; if the cat experimented with is not an experienced rover with a wide topographical knowledge of the region, which thus becomes full of finger-posts; and if the percentage of failures is small—then we must face an unsolved problem. The ordinary solution is to postulate "a sense of direction," but this is only a verbal solution unless we can give some physiological content to the phrase. By hypothesis it is something apart, a capacity independent of enregistrements of ordinary sensory experience and even muscle-memory, but it must have a location and a way of working. Until we know more about it, a "sense of direction" is just a

term for a puzzling capacity. This is the type of "unsolved problem" which will almost certainly disappear as experimental data increase.

When a worker-bee is taken from the hive, put into a box and into the experimenter's pocket, carried to a distance of half a mile or so and then liberated, what happens? It usually ascends into the air, circles round once or twice, and then makes "a bee line" for home. But if the hive has been meanwhile shifted two or three yards to one side, the bee is for a time bamboozled. Before the young worker begins foraging, she usually has a number of trial trips in the vicinity of the hive, and she has been watched taking her bearings by hovering for awhile with her face to her home. The near-at-hand geography is very quickly learned. Thus Dr. John Anderson, a notable Aberdeen apicultural authority, has told us that a stock of bees transported to a new environment, on a steamer journey of three days, were busy foraging within forty-five minutes of their arrival in their new field of operations. "It had taken the strangers just three-quarters of an hour to locate the position of their home, and to find the treasures of the field." This implies a rapidly working visualizing power, in the sense of recognizing landmarks, at least.

Professor Yung of Geneva made the neat experiment of carrying thirteen marked bees about half a mile out of town, liberating them in the open country. All of them returned to the hive, eleven of them ahead of the experimenter. But when he took a second batch out on the lake none returned. The suggestion is obvious, that the power of homing in bees depends upon topographical cues. There were no landmarks on the water! This theory of orientation is confirmed by the distance-limits, for if bees are taken beyond a radius of about two and a half miles from the hive, they fail to find their way home.

They are successful only within the limits of their foraging ; and the degree to which they learn their geography naturally varies from place to place according to the need for knowledge. The habit of rising high before they start for home probably expresses an attempt to catch sight of some outstanding object, such as a tall chimney.

Hundreds of careful experiments have been made in regard to the homing power of bees, wasps, and ants, not to speak of less well endowed animals, such as snails, limpets, and crabs ; and the general conclusion stands out clearly, that most of the phenomena can be interpreted in terms of a matter-of-fact apprenticeship to the adjacent environment. There is an enregistering of sensory cues, oftenest visual, olfactory, and tactile, but sometimes more subtle, such as feeling of slope and of pressure. Some cases are puzzling unless we allow a capacity for enregistering and recalling muscular movements ; and there are a few very remarkable experiments with ants and bees that remain to us quite inexplicable. On the whole, however, the way-finding illustrated by most of the lower animals is a solved problem, depending on an individual learning of sensory cues, which, of course, presupposes a noteworthy inborn susceptibility to external influences.

By experimental methods it has been proved up to the hilt that migratory birds may return from their winter quarters in Africa to their summer quarters in Britain, or from the Hawaiian Islands to Alaska, or from Virginia to Labrador, and so forth. More than that, however, is certain, for it has been proved that birds marked on the foot with a light aluminium ring (or otherwise) may return from the South to their precise birthplace in the North. As the distances are often great, this homing of migrant birds is the most striking instance of orientation, and it has been much studied.

What we are facing at present is not the general problem of the migration of birds, but the special problem of their remarkable, though by no means unchequered, success in "way-finding." The impulse to migrate is probably an expression of an engrained or hereditary racial custom, which has been gradually established in the course of many hundreds of generations, Natural Selection sifting out those variants that were most successful in migrating. But it is necessary to give some content or meaning to such terms as "sense of direction" or "capacity for way-finding."

Suppose we admit that migratory birds are actuated twice a year by a hereditary urge of restlessness, which prompts a change of haunt; suppose we also admit that the urge is liberated by external seasonal stimuli and also by internal constitutional stimuli; suppose we allow that the custom is in several ways very advantageous; the question then arises: How do the migrants succeed in finding suitable winter quarters (their "unseen goal," of which the youngsters of the year have had no experience), and how do they succeed in returning the following spring to their native land, and even to the farm-stead where they were born? Is it simply that they follow cues that lead them away from the place where they have become restless and ill at ease, and, if so, what are these cues? Are they mainly visual, or do they imply some keen sensitiveness to temperature, to pressure, to magnetic currents, or other external stimuli? Or is there some unknown kind of sensory cue that works well, and justifies us in speaking (in more or less conscious ignorance) of a *sense of direction*? This is an unsolved problem of the type that will remain unsolved until more facts are forthcoming.

In his interesting book, *How Animals Find Their Way About* (Kegan Paul, 1928), Rabaud considers in some detail

this problem of homing migrants, and comes to the conclusion that all the phenomena can be explained in terms of "ordinary sensory cues." But when one looks for the explanation or analytic description, it seems very far from being adequate; and Rabaud's exemplary parsimony with hypotheses seems somewhat like a scientific pious opinion. He points out fairly enough that as regards backboneless animals, the hypothesis of a special sense of direction has proved unnecessary, for, as we have seen, increased knowledge has shown that ants and bees and the like learn to utilize sensory cues in finding their way home. So in regard to birds, Rabaud thinks, the hypothesis of a special sense of direction will turn out to be unnecessary. Perhaps he is right, but it is hard to discover what sensory cues serve to guide migrant birds flying in the dark, across the pathless sea, over areas never before traversed. No doubt the sensory impressions are many and diverse, as airmen well know, but how do they serve the migrant birds as cues? The hypothesis of a special sense of direction is not an assumption of anything magical or mystical; it merely expresses our inability to explain the successful flight in terms of ordinary sensory guidance.

Rabaud makes a point of distinguishing migration and orientation. The former is a periodic displacement "under the incontestable influence of stimulation from the surroundings—temperature, illumination, hygrometric state, etc.," and it is illustrated in the major part of the flight, when birds leave a region that has become uninhabitable, whereas orientation is illustrated when birds approach a known region. Then sensory orientation takes the reins. But this does not seem to us to be a legitimate distinction. We wish to know why young birds, that never left the parish before, set off at the end of summer, while the conditions are still far from being uncomfortable, and set off in the right direction, and

continue so flying in the darkness and across great wastes of sea.

Moreover, the experiments of Watson and Lashley on the Terns of the Tortugas show that, apart from migration, it is possible for these birds to return to their nests (of course, with variable success) from distances of over 800 miles, and even from seas which they had not previously visited.

We have refrained from referring to the case of carrier pigeons, because it is complicated by man's graduated education of the homers and by his prolonged selection of the more adept. Moreover, the dominant importance of visual cues in this case is indicated by the frequency of failure when vision is disturbed, and by the strangely long time that the homing flight takes when it is over new ground—a peculiarity which points to many tentative flights in different directions. But for migrant birds we think there is still strong reason for regarding their success in orientation as an unsolved problem—which is all that we personally mean by postulating a sense of direction.

CHAPTER XXXI

WALKING IN A CIRCLE

Many years ago on a holiday in the West of Scotland we were overtaken by a dense fog while crossing an easy stretch of moorland. We were not in a hurry and there were no serious snags to be afraid of, so we walked on and on, knowing that in two or three miles we should strike a well-known road. But after a long walk we had not reached the highway, and we were glad to fall in with a shepherd who was smoking patiently beside a fold. We asked the way and were told that if we kept straight on for a quarter of an hour we should be on the road we knew. So on we went with lighter foot, resolved to turn neither to our right nor to our left, and the result was that in half an hour we reached the shepherd again from a different angle. We had wandered round in a clock-spring spiral, which was almost a circle with a comparatively short radius. The shepherd advised us to wait a bit, as it was going to clear; and it is obvious that we survived to tell the tale.

Our experience was a commonplace instance of a well-known fact that men who lose their way in fogs and snowstorms, dense forests and darkness, tend to go round in a circle or in a loose spiral. The same circling or spiralling has been observed in foxes, rabbits, and antelopes hard pressed in the chase. In their case fear serves, like the fog in ours, to put the usual steering arrangements out of gear.

The problem of spiral movement has been recently studied with great care by Professor A. A. Schaeffer, of the University of Kansas, who has accumulated a mass of data and made many maps showing the actual paths

taken by blindfolded walkers and swimmers, rowers and car-drivers. He notices that there are numerous references to "going round and round in circles" in the folklore of many peoples, especially among those of northern latitudes where fogs and snowstorms are common. In conventionalized clock-spring spirals carved on a reindeer antler by some Aurignacian sportsman 20,000 years ago, he finds the first entry in the bibliography of spiral movement or spirokinesis in man. But this seems to savour of the expert's enthusiasm for his subject.

When man has a definite goal in view, such as walking straight across a moor, he takes account of landmarks if they are available, and the degree to which this is necessary and conscious varies greatly with individuals and with experience. In rowing across a wide strait without obvious landmarks, fishermen are much more successful than amateurs; and it is probable that sky and sea afford information to the expert that is not available to the ordinary man. In the accidental absence of a compass, some experienced explorers give a good account of themselves in traversing a difficult region not previously visited, though carefully studied on the map. One of these gifted persons has told us that he guides himself in reference to a previous visualizing of the lie of the land, but that he trusts largely to subconscious orientation. He has repeatedly achieved an almost uncanny success in very dense fog, which obliterated everything; and in regard to this, the only suggestion he is able to make is that he has a general idea of the lie of the land and keeps a sort of dead reckoning. He reports that in trying to walk straight in the fog he is conscious of close attention to his locomotion, although there is nothing environmental to see, and that a condition of success is silence on the part of his companions. But most people in similar circumstances describe circles or spirals, sometimes to the right,

sometimes to the left, and often, as the tracks show, with a reversal of the direction in the course of the progression, if such it may be called.

It is interesting to find that many free-swimming animals habitually move in corkscrew or helicoid spirals. This is seen among flagellate and ciliated Infusorians, Rotifers, young worms, larval ascidians, small crustaceans, and so forth. It occurs also in some free-swimming zoospores of Algæ. In fact, it is of widespread occurrence, unless the creature is in the sway of some strong sensory stimulus towards or away from which the locomotion is automatically or intelligently directed in a more or less straight line. So that what man does in a fog or the like is to hark back to an old-fashioned mode of progression. Making straight for a goal under sensory or intelligent guidance has been superposed on a more primitive spirokinesis, which is revealed by man and some mammals in abnormal circumstances. Of course terrestrial progression in a spiral is in two dimensions, whereas aquatic animals can move in three.

Schaeffer made many experiments on snow-covered fields, where an accurate record was left by the footsteps; and his general result is that blindfolded persons walking in what they intend to be a straight path actually move in a more or less regular clock-spring spiral. The same is seen when a blindfolded man drives a car in a field or gives directions to the driver. It is also seen in swimming blindfold. One and the same person may walk or swim or drive both in right-spiral turns and left-spiral turns in different experiments, or sometimes in the same experiment. The direction does not seem to have anything to do with right-handedness or left-handedness; but there may be a marked individuality in the paths made by different people. Thus some made much wider and more irregular spiral turns than others, and

showed frequent reversals in direction instead of few or none.

Those who have the experience of losing their way in a fog are not aware that they are spiralling, though they may come to suspect that this is the case. Similarly the blindfolded persons in the experiments think that they are going straight. So we may conclude that consciousness gets no direct report on the subject. Yet everything points to the conclusion that the spiralling is the outcome of commands from the central nervous system, and probably from the area that has to do with co-ordinating locomotion. We must reject the widespread idea that the spiral turning is due to any pronounced asymmetry in the legs or in the body generally, for that is far too simple an interpretation, and does not apply to many of the lower motile organisms. But there may be, as Schaeffer believes, some subtler locomotor asymmetry, which makes the creature turn strongly to one side. But in those that move, like man, in two dimensions, the reversibility of the direction is a further puzzle. So is man's mental proclivity to vicious circles.

SHOWERS OF ANIMALS

There is no doubt that animals occasionally drop from the air on to the ground. Many of the records are quite untrustworthy, but there are facts behind the fictions. Just as the "stooks" in the harvest-field are sometimes gripped by a local whirlwind and made to dance in the air, the centre of the vortex sometimes travelling from field to field, so aquatic animals, such as insect-larvæ, water-snails, minnows, and tadpoles, are sometimes caught up, especially from ponds and shallow reaches of streams, and whirled along to places where they are not unreasonably regarded as having fallen from the sky. In most cases they can be traced to some water-basin not very far off. Many alleged cases of showers of animals are critically discussed by P. H. Gosse in the second series of his fine old book, called *The Romance of Natural History* (1867).

There is circumstantial evidence of the lifting up and redepositing of tadpoles and also of very small frogs (the size of one's little finger-nail), little fishes of various kinds, small snails, especially freshwater snails, insect-larvæ such as those of gnats, and several other different kinds of animals.

"Showers of blood" have been sometimes recorded, and these are of two different kinds. They may be due to hundreds of small red river-worms (like *Tubifex*) or to the aquatic "blood worms," the red larvæ of harlequin flies, insects of the genus *Chironomus* and related genera. In these cases the little animals have been whirled out of the water and showered down somewhere else. They have the same red blood pigment (hæmoglobin) as back-boned animals, so it is not wide of the mark to speak of

a "shower of blood." Very different, however, are other red showers, which are due to the carrying up and redepositing of innumerable reddish unicellular organisms, sometimes Infusorians, sometimes Algæ, sometimes Fungi. To such minute organisms the phenomenon of "red snow" is also due.

Another sight that has often provoked amazement is the descent of numerous ants from the air. These are the winged males and females which have left the community with its wingless workers, and have had their "nuptial flight," often in huge numbers. The pairing takes place in the air, and then there is a sinking to earth. In a short time the males die. The females shed their wings and settle down to be the mothers of another community. We see, then, that it is not fiction to speak of a shower of ants.

Another true shower is a fall of honey-dew. It may be seen and felt as it drips from the lime-trees; in a well-shaded street of a continental town we have seen the pavement wet with the strange moisture. Honey-dew is a sugary exudation from the food-canal of the Aphides or green-flies, or from related insects. As already mentioned, some kinds of manna are exudations from insects, while other kinds exude from plants.

In many parts of the country there are "sulphur showers" every year. These are genuine enough except that there is no sulphur. Big tracts of ground are sometimes covered with yellowish, somewhat pease-meal-like dust and the herbage may be powdered thickly. This is due to a great liberation of pollen from the pine-trees and other Conifers of the forest; and as each grain has two little bladder-like floats, the pollen may be carried far on the wings of the wind. It sometimes rises like smoke from the trees, and when the cloud sinks to the ground, far away from the forest, who can wonder that it should

be looked at with puzzled eyes and given some credulous or superstitious interpretation? But it is not from heaven that the sulphur shower is supposed to have come!

When solid bodies travelling in space get within the earth's gravitational grip and approach it at a high velocity, the sudden compression of the atmospheric gases produces so much heat that the dark intruder is lighted up for a brief moment before it passes into the form of gas and "goes out." Such are the "shooting stars," or, to give them a worse name, "falling stars," that everyone knows. But it sometimes happens that a meteoric stone, separated perhaps from a comet's tail, comes solid to earth; and there are many of them, both large and small, to be seen in museums. If anyone wishes to call them "thunderbolts" there is no harm done. But the naturalist must protest against giving this name to the strange fossils called Belemnites, which are common in some parts of the country. They are often the length and thickness of our middle finger, but they may be considerably larger. They are like Martini-Henry rifle-bullets in shape, and as hard as rock. Persistently they are called thunderbolts, and they are certainly like projectiles; but they never fall from the sky, and they are simply the fossilized remains of the internal shell of Belemnites, an extinct type of cuttle-fish or Cephalopod. It is to the depths of an ancient sea, not to the heights of the air, that these false thunderbolts belong.

There are two interesting reasons for not thinking too lightly of the true records of living creatures that sink to the earth from the air. The one reason is that many microbes are wafted about in air-currents from one place to another, and not only the infinitely small bacteria and the like, but larger living things as well, such as Infusorians and the eggs of small animals. It would be impossible to understand the appearance of small animals,

such as threadworms, in exposed organic substances, in the forgotten saucer of paste, in the vinegar cruet left unstoppered, and so forth, unless there were a transport of minute eggs and larvæ in draughts and gusts of air. No doubt the transport of microbes is often due to insects which carry them in or on their bodies, but there is also passive aerial dissemination.

The second reason is the hypothesis that very simple forms of life may *possibly* have reached the cool earth long ago *from elsewhere*. They might be wrapped up in the chinks of a meteorite, for instance, or borne along amid cosmic dust. With this suggestion the names of Helmholtz, Kelvin, and Arrhenius are associated, so it must not be dismissed with a contemptuous smile. It must be kept in mind as *a possibility*, for we know that very simple forms of life can survive for a long time extraordinary extremes of temperature and other adverse conditions.

HOW IS THE EARTH KEPT SO CLEAN?

Especially at the Fall of the year, which is a great time for dying, the question arises: How is the earth kept so clean? What an efficient "Cleansing Department" there must be, there are so few dead animals lying about! All through the year, no doubt, there is this process of tidying, cleaning, and burying, but its thoroughness is very marked in autumn when there is much bare ground; yet there is little tangible evidence of the terrible thinning of the ranks of animal life after the crowdedness of summer.

Long ago W. H. Hudson drew a fine picture of the dying huanaco, that is to say, the wild form of the llama and alpaca—the small camel of South America. It seems that at the southern extremity of Patagonia the huanacos have a "dying-place" to which they repair at the approach of death. Darwin noticed this on his *Beagle* voyage and pointed out that the exhausted animals must in most cases have had strength enough left to crawl among and beneath the thick bushes. This strange habit may in part express the natural desire of the aged or infirm to get away from the fatiguing bustle of the herd, and possibly to escape from the way that some gregarious mammals have of getting rid of sickly or wounded relatives, whose persistent presence is apt to be a source of danger. But both these suggestions sound very anthropomorphic, and we may safely conclude that the dying huanacos do *not* set off on their final pilgrimage with the purpose of finding a quiet place to die in. Moreover, it is only in Southern Patagonia that the huanacos have dying-places.

Much more credible, we think, is Hudson's theory that the dying-places were ancient shelters from the deep snow and deadly cold, and that the exhausted huanacos are still obeying an old instinct which climatic changes have robbed of its original significance. It is known that certain animals that become comatose in winter, such as some of the rattle-snakes, go back year after year to the old winter-den; and it is also true of some of the true hibernating mammals that they go back to the same winter quarters over and over again. If this happened on a large scale, and if the lethargy and the winter sleep ended fatally, as it sometimes does, the result would be a cemetery distantly comparable to that of the huanacós of Southern Patagonia.

But the point we wish to make is simply that many animals retreat to shelters beneath the ground, or in crannies among the rocks, or in crevices inside plants, where many of them die and are buried. The young queen-wasps of this year, sole survivors of the large summer community, hide themselves in early autumn, each in her own place, under the thatch of a cottage or the loosened bark of a tree; and while some will "sleep" the winter away, there are others that will never re-awaken.

Then again, no small amount of cleaning up is due to the ceaseless conjugation of the verb "to eat" that goes on in Wild Nature. So many animals depend upon "crumbs" in the wide sense—minute fragments of plants, such as fallen bud-scales, unconsidered trifles of insects, such as the dead bodies of midges killed by the evening frost. We have no great love for starlings when they become numerous, but it is interesting to watch the thorough way in which they advance in a long row over a lawn, pecking almost without stopping, and evidently making a good meal of minutiae, the nature of which in

some cases we utterly fail to detect without a post-mortem. Thus one of the reasons for the cleanness of the earth is the circulation of matter which animal appetite secures. The dead creature is often devoured by another before it has had time to decay; its material substance finds a new embodiment, its protoplasm a fresh avatar. The flux of animate nature is a ceaseless cycle of re-incarnations.

Those who live in the vicinity of deer forests have sometimes remarked on the relative rarity of the cast-off antlers—substantial organic structures which cannot very quickly disappear. Part of the explanation is that the stags eat their lost decorations, the erosions made by the lower incisors being sometimes clearly visible when the strange meal has been interrupted.

Especially in the autumn we cannot overlook the cleansing and tidying that is due to the burying activity of the multitudinous earthworms. No doubt they are chiefly concerned with taking leaves and other parts of plants into their burrows, partly for food when they decay, partly to make the underground retreats more comfortable; but it is of interest to notice that their somewhat blunt instinct extends to things like feathers and pieces of string, as we have often demonstrated.

Ultimately, of course, the decay of a dead animal is due to the action of bacteria, which also bring about the rotting of withered leaves and herbage, but our question is why we see comparatively little of the dead bodies of animals. Many animals go into shelters, often underground; some are devoured, living or dead, by other animals; but there is another answer—to be found in the industry of numerous creatures that are professionally, so to speak, the sextons of the earth. Very typical are the species of *Necrophorus*, beetles which collect underneath a dead bird or the like and energetically dig a grave.

Their instinct is to excavate the earth below the dead body so that there is a rapid sinking downwards. Fifty of these sexton-beetles, some in funereal black and other species more cheerfully attired, have been found working underneath a dead crow; and unless they are numerous they do not succeed with a largish animal. For they have to work against time, the "object" being to secure a suitable cradle for the young. If the burial takes too long the tissues are apt to dry up, and flies are also likely to forestall the beetles. Either of these contingencies would be prejudicial to the beetles' interests—it is very difficult to speak of "purpose" or "end"—for the grubs must have a moist environment and soft food, and the fewer competitors they have the better. After the larvæ reach their full size they leave their cadaverous cradle and pupate in the adjacent earth, eventually coming to the surface as sexton beetles. The nearly related carrion beetles (*Silpha*) often eat the dead bodies of small mammals and also use them as cradles, but in this group there is no burial. Thus the behaviour of *Silpha* may be regarded as a stage in the evolution of the carrion-using instinct, which has its fuller expression in *Necrophorus*.

If the dead body of a little mammal, such as a shrew, is left undevoured on the surface of the ground, and unburied by the sexton beetles, it may pass through two stages. In the first place, it is almost sure to be utilized by flesh-flies of some sort as a receptacle for the eggs and a feeding-ground for the larvæ. But after the larvæ have become flies and flown away, what remains of the shrew's body is exploited by animals which Verhoeff has called the "secondary carrion fauna," such as several kinds of centipedes, various species of mites, some of the energetic ants, and not a few smaller beetles, such as a remarkable one with the startling name *Thanatophilus* (the death-

lover). Eventually there is nothing left but a little débris, which bacteria reduce to the lowest common denominator of the inorganic. This, then, becomes the food of plants and so enters on another incarnation. And so the world goes round !

DO PLANTS BEHAVE?

Of recent years the outlook of science on the plant world has become more generous. It has been proved that the average plant is alive more intensely than was suspected. Just as there is, so to speak, a good deal of the plant within such animals as arborescent corals and the colonies of sedentary sea-squirts which are wrapped up in tunics composed of the characteristic vegetable substance cellulose, so it may be said that there is much of the animal in many a plant, such as the carnivorous Sundew, the exquisitely sensitive Mimosa, and the mobile tendril-bearers like Bryony and Vine. What is one to make of the Indian telegraph plant, *Desmodium gyrans*, that lives on the steamy banks of the Ganges, whose basal leaflets, two for each leaf, are continually executing minute somewhat semaphore-like movements? Some very simple plants like the Oscillatorias are in constant, and somewhat puzzling, movement.

There is no doubt that plants and animals are on entirely different lines of evolution. No greater dichotomy has ever occurred than that which made the genealogical tree of living creatures somewhat V-like, with plants on the one fork and animals on the other, the base of the V including the Protists, which have not taken a decisive step towards either of the two great paths. The fundamental difference lies, of course, in the plant's capacity for feeding at a low chemical level and utilising the reddish rays of the sunlight to build up carbon-compounds. It does this far in excess of its needs, so that its up-building or constructive processes are far greater than its down-breaking or disruptive processes. The

animal, on the other hand, feeds at a high chemical level on proteins, carbohydrates, and fats, which are directly or indirectly due to plants. With this complex food, rich in potential energy, the animal is able to live more or less explosively, its expenditure often close up to its income.

But since the days of Claude Bernard it has been clearly recognized that in spite of the radical dichotomy between plants and animals there are great samenesses in their physiological routine. If we study a green plant at night, we find that it is taking in oxygen and giving out carbon dioxide, exactly like the animal in the same room, or the burning candle for that matter. In other words, the plant shows the function of respiration, though this is masked during daylight by the converse process of splitting up carbon dioxide and liberating oxygen—a process to which we owe our breathable air. Similarly the plant has digestive ferments, not merely in the exceptional insect-eaters, like Sundew and Venus's Fly-Trap, but in every green leaf, changing starch into sugar, and in every sprouting seed, mobilizing protein into peptone or the like. To an extent that was unsuspected a quarter of a century ago, plants form nitrogenous waste-products, sometimes even urea, as the ashes of their living fires. There is no doubt again that some plants have hormones, those mysteriously potent internal drugs which are so indispensable in the internal economy of the higher animals at least. In spite of radical differences, there are close resemblances between plants and animals.

The beech-tree feeds and grows, digests and breathes as really as does the squirrel on its branches. Both develop from fertilized egg-cells; both are built up of cells and modifications of cells. And even when we think of moving and feeling, so characteristic of animals, do we not see them both in the tendrils of climbers, the leaves and

leaflets of the Sensitive Plant, the tentacles of the Sundew, the stamens of the rock-rose, the stigma of the musk, and many other instances? With particular reference to the illuminating work of Sir Jagadis Chunder Bose, we wish to extend this conception of the living plant.

Bose has given his strenuous life to answering such questions as these: Are all plants sensitive to stimulus? Is there, as in animals, a latent period between receiving the stimulus and giving an answer? Does an impulse spread through a plant like the nerve impulse in an animal? Are there pulsations in plants comparable to the beating heart of animals? What are the conditions that retard or accelerate growth? By very ingenious appliances he has been able to make "the dumb plant the most eloquent chronicler of its inner life and experiences," and he has been led by the plant's autographs to the conclusion that "there is no life-reaction in even the highest animal which has not been foreshadowed in the life of the plant."

By attaching a delicate recorder to the Sensitive Plant, called in Bengal the "coy maiden," it is possible to study its responses with great precision. In answer to a blow, the beautiful compound pinnate leaf sinks down as a whole; the four secondary ribs are drawn together; their numerous leaflets close upwards. The movements are due to changes in the sensitive cushions at the base of the part that moves, each movement being due to the fact that the upper half of each cushion is less active, less contractile, than the lower half. The reason why *Mimosa* is much more responsive than the ordinary plants is to be found in this inequality in the sensitiveness of the two surfaces. Similarly in a tendril, notably sensitive and motile, the outer or convex surface of the coiling portion is more sensitive and more contractile than the inner or convex surface; and this accounts for the con-

tinued coiling. If a tendril be cut off and freed from its support, a strong electric shock causes it to uncurl convulsively like a writhing worm. But it would not do this unless it were unequally sensitive on its two sides.

In an animal an appreciable time elapses between the stimulus and the movement that answers back. It is about one-hundredth of a second for the frog; very much longer for the sluggish tortoise. It occurs also in plants, but may be only 0.075 of a second; it is lengthened out, however, by fatigue, or shade, or cold. A plant can "notice" a wisp of cloud passing across the sun. As regards light-waves, a plant may be many times more sensitive than man. As regards the sensitiveness of the human tongue to very feeble electric currents, the plant called *Biophytum* is found to be eight times more sensitive than a European and four times more than a Hindu.

The sinking down of the leaf of the Sensitive Plant, *Mimosa pudica*, may occur in a second, but some other leaves take a minute to pass into the resting position. Most botanists believe that the motility is due to a change in the internal pressure or turgor of certain cells, like those of the cushion in the Sensitive Plant, but Bose believes that there is a specific "active substance" in the protoplasm of these cells. In any case it is very interesting to know that the responses vary with the purity of the air, with the temperature and illumination, and that plants may be fatigued, drugged, or poisoned just like animals.

There is no doubt that a thrill may pass rapidly from one part of a plant to another; and according to Sir Jagadis Chunder Bose there is no evading the conclusion that certain lines of cells in the plant act as nerves. But what he regards as a nerve is interpreted by other investigators as a conduit for hormones. From the general biological point of view the important fact is that plants do show activities which may be reasonably compared to

nervous thrills. One must go farther and say that some exceptional plants, like the Sensitive Plant, show answers-back which are uncommonly like "reflex actions." But they may be the analogue of reflex actions, although there are not in the strict sense any nerves. Similarly, although the sap-current may be reasonably compared to the circulation of the blood, and although there may be a rhythm in the activity of certain cells that help to keep the current a-going, we suspect that to press the comparison with an animal's heart, as Bosc does, is more of a hindrance than a help. One must remember the wide divergence of the plant and animal branches of the genealogical tree. On general grounds one would expect them to solve the same problems in different ways.

If a Venus's Fly-Trap (*Dionæa*) is cheated two or three times with faked "fly" it ceases to catch. Yet in a short time it "forgets," and may be cheated again. Its memory is short, but in this enregistering of experience so that subsequent behaviour is influenced, and in similar facts which Bosc has disclosed, it is difficult to deny the emergence of "mind."

THE ASCENT OF SAP.—All over the country in early summer there is stretched a green veil under which the inorganic simplicities of carbon-dioxide and water are raised into the organic complexities of sugar and even more intricate substances. This fundamental process of photo-synthesis implies an ascent of soil-water from the roots, the source of supply, to the leaves, the seat of utilization and loss. This is the transpiration stream, and there has been a long enquiry into the conditions of its flow, especially in the case of tall trees where it has to go so far up-hill. There are still rival theories, but the trend of botanical opinion seems to be markedly in favour of the view that the water in the tracheæ of

the wood "inevitably passes into a state of tension when it is reduced in volume by abstraction from one or both ends." The abstraction of water by the leaf-cells that are in contact with the upper ends of the water-pipe system draws the water up in a state of tension from the lower parts. There are continuous water-columns in the tracheæ of the wood, and these conducting pipes undergo compression when water is lost by transpiration from the leaves, and this gives the water a tensile strength which has been measured and shown to be adequate to account for the phenomena observed. This is clearly explained in Professor H. H. Dixon's *Transpiration Stream*, a little book that the enquiring mind should read. There are some investigators, such as Sir Jagadis Chunder Bose, who insist that it is necessary to take account of vital cell-processes in an analysis of the ascent of sap. Thus Bose declares that "the maintenance of the ascent of sap is effected by the rhythmic activity of living cells in the stem." We cannot state his case here, but the advocates of the Cohesion Theory think that the tensile strength of water in the delicate pipes of the wood-tracheæ is sufficient to account for the facts. But this does not exclude the vital action of the transpiring cells in the leaf, which absorb water from the pipes and emit it as vapour into the intercellular spaces.

In the botanical teaching of a century ago, it was maintained that the elaborated "sap" with its sugar and the like came down by vessels of the bast. But investigation has shown that proteins and ferments are carried by the tracheæ of the wood. In fact the wood is, in Professor Dixon's words, "a specialized reservoir of liquid food-stuffs within the plant." Altered tension leads to a flow up, but also to a flow down. Between the wood reservoir and the body of the plant come intermediary, middlemen elements: namely (1) the bast, (2) the medullary rays

penetrating into the wood, and (3) their extensions as the wood-parenchyma among the tracheæ. But these tissues not only abstract from and contribute to the contents of the wood-tracheæ, they probably make ferments and even hormones which keep the pipes alive and clear. The circulatory system in plants becomes more and more animal-like.

THE FRAGRANCE OF FLOWERS.—There seems to be little evidence in support of the opinion, often expressed, that man's sense of smell is undergoing racial degeneration. It is not, indeed, so important to man as to many other creatures who use the sense of smell to find their food, or their way home, or to discover the approach of enemies or kindred. Yet it remains very acute in mankind, and what is sometimes attributed to racial degeneration is mainly the result of individual fatigue of the olfactory sense by strong odours, such as those of tobacco and tarmacadam. The sense of smell remains of importance to man in enabling him to detect bad food, foul air, and dirtiness generally, and in giving, along with the allied sense of taste, an additional pleasure and piquancy to his meals. Olfactory stimuli from flowers should also be among the normal constituents in every man's joy of life.

Just as it is a good plan to study the migrant birds as they arrive in their companies, before there is an embarrassing multitude of them all together, so it is useful to revive our olfactory impression of flowers before Flora's feast is fully spread. Thus we enjoy in spring the fragrance of daffodils, jonquils, primroses, some rhododendrons, violets, wallflowers, and other early blossoming plants. No one should be ashamed of his enjoyment of the first dish of rhubarb for the year, the first salmon, the first strawberries, and so forth—we should be a wholesomer

people if we cared more about these things—so we should attach importance to the first whiff of violets!

Our first question enquires into the nature of these messengers that travel from the flowers to the olfactory patches in our nostrils. The general answer is that they are the volatile molecules of essential oils, meaning by volatile that the molecules are set free from a fluid, or, occasionally it may be, from a solid state, and are diffused freely by currents in the air. It is convenient to speak of the essential oils of flowers as attars, such as attar of roses. They are mixtures of various chemical substances, which are by-products in the life of the flower. Thus, Dr. F. A. Hampton tells us in his admirable book on *The Scent of Flowers* that the attars may include esters as in orange blossom and some magnolias, alcohols as in roses, aldehydes as in hawthorn, ketones as in violets, and so on. One essential oil from a flower may include as many as half a dozen complex chemical substances, and the messengers that issue forth from the petals may be accompanied by others from the leaves, as in Sweet Bay, Eucalyptus, and Southernwood or Apple-Ringie—the last reminiscent of the long sermons of days gone by. We say that a flower has a red colour because the floral pigment reflects only the red rays of the sunlight that falls upon it; but it does not seem to be practicable at present to suggest, except to a very limited extent, why a particular chemical composition should be associated with a particular odour.

The second question is of profound interest, but at present almost hopelessly difficult; it enquires into the direct physiological significance of the odoriferous substances in the chemical routine of the fragrant plant. If we probe into the black pigment of a crow, we find that it is due to the action of a common ferment, tyrosinase, on an amino-acid formed by a breaking up of one or

more of the proteins which are universally present in living matter. So, in this case, that of the pigments called melanins, there is no particular difficulty in regard to the raw materials of their production. But there is great difficulty in regard to most of the odoriferous substances of plants. Perhaps it is safe to say, however, that while some mean one thing, and some another, the majority are of the nature of waste-products. Just as man makes perfumes out of what used to be thrown away as useless by-products, so the plant makes fragrance out of its waste. It is not a mere chemical curiosity that the valeric acid which cats appreciate in Valerians is also found in animal sweat. Many of the flower-scents seem to be due to substances which are end-products in the breaking down of proteins, or to changes in these end-products by subsequent recombination. Here it is useful to recall the familiar fact that when bacteria decompose organic matter, partly consisting of proteins, they often give rise in the first instance to pleasant smells, which are afterwards replaced by the repulsive odours of putrefaction. It will be understood, of course, that the pleasantness or repulsiveness of an odoriferous substance has nothing to do with its primary physiological significance in the organism in which it is produced.

If many flower-scents are end-products and by-products of the plant's chemical routine, many facts become more intelligible. Thus we can understand why some of the simpler scent-substances occur through and through the plant, as in the familiar case of peppermint; or how a scent in the leaves may be changed into a slightly different scent in the flowers, as when the geraniol of the Rose-Leaf Geranium is oxidized into the subtler lemon-scented citral of the blossoms. In many cases the flower-scent is an elaboration of the leaf-scent. Dr. Hampton notices the interesting point that most of the

highly specialized scents, such as those of night-blooming flowers, are found in plants with scentless leaves. Subtle scent is associated with specialized metabolism, and in some orchids the pistil tip has actually a different scent from the rest of the flower! Also very interesting are those plants whose scent changes as their metabolism or chemical routine changes; thus an orchid may smell of heliotrope in the morning and lilac at night, or of a carnation during the day and of a fox at night.

The third question enquires into the use of the scents to the plants, and the answer is relatively easy, though we have still much to learn. In some plants the odoriferous substances help to repel browsing animals, even goats, or the all too common snails and slugs, or those unwelcome insects whose visits are altogether predatory, without assisting in pollination. Sometimes the scent-substances may be antiseptic against moulds and microbes.

But in many cases the main use of the fragrance is undoubtedly as an advertisement to the bees and butterflies and two-winged flies that come to the flowers for food, and unconsciously secure cross-pollination. Careful experiments have shown that hive-bees, to take one case, have hundreds of olfactory pore-canals on their feelers, with touch bristles interspersed; that they form associations between a particular odour and a particularly profitable flower; and that they are able, by smell, to keep to one kind of blossom for the whole day, a procedure profitable to themselves and also to the plants they visit.

OPENING AND CLOSING OF FLOWERS.—How familiar we are with the opening and closing of flowers in relation to the waxing and waning light of day, or conversely, yet how vague we remain as to what happens. It is an old problem still being worked at. It has been shown that at, or immediately before, the time of movement the

epidermis on the side opposite that to which the petals curve contains a cell-sap with a higher osmotic concentration than that on the other side. Thus, at the time of opening, the inner epidermis of the dandelion's florets contains a sap of higher osmotic pressure than that on the outer side. But, at the time of closing, the reverse relation is observed. When a flower collapses, the osmotic concentration of the epidermal sap falls on both surfaces. It seems probable, then, that the epidermis has some share in floral movement, and it may be chiefly effective in flowers with very thin petals. Yet, as the change in relative osmotic concentration between the inner and outer epidermis of the petals is evident before the actual movement, it may represent a preparation for the opening or closing rather than the immediate cause. The tissue on the active side may expand in response to the increased turgidity developed by the denser sap, since the concentration of the epidermis is usually above that of the adjacent parenchyma. But another factor may be the water-loss on the passive side. Vital movements are always difficult to understand : in plants as in animals, unlike mechanisms, the engines are conspicuously soft and watery.

THE COLOURS OF FLOWERS.—Plants contain pigments or coloured substances of two distinct types. There are in the first place the vegetative pigments, such as green chlorophyll, which are intimately bound up with the life of the cells and are in fact the principal reagents in the laboratory of the leaf. On the other hand there are more soluble pigments which colour the sap of the cells of flower petals. Whatever their value to the plant, they certainly do not share in the chemical syntheses of the green leaf.

These flower pigments or anthocyanins are, as everyone knows, of the most diverse colours. It has only

been quite recently discovered that all these variously coloured pigments are chemically closely related to each other. The blue colour of the cornflower, the orange of *Tropæolum majus*, and the red of the berries of the Mountain Ash or Rowan, are but different shufflings of almost the same chemical cards.

The anthocyanin pigments belong to the great class of the glucosides, in which one or more molecules of glucose or grape-sugar are united with other organic groups. The nature of these has been brilliantly investigated by Willstätter and his pupils, and several pigments have been built up in the laboratory. Chemically regarded, these compounds are interesting in connection with the relation of colour to chemical structure. Moreover, in certain examples the atom of oxygen is held by four chemical bonds simultancously, instead of two, as is usually the case.

WITHERING LEAVES.—Leaves work hard all the summer; they use the reddish rays of the sunshine to help them to build up carbon compounds; and they are in some measure worn out in autumn. So they begin to die, and they die in many cases very beautifully.

If they continued active they would be sources of weakness, for they would be using and losing water which becomes less and less available as the winter draws near. Even if they obtained sufficient water, it might be apt to freeze in the delicate tissues, and then the leaves would prove vulnerable points for the tree. So in the great majority of cases they fall.

Across the base of the leaf-stalk there grows a special separating layer of cells, differing from their neighbours in showing greater turgescence, denser protoplasm, more abundant starch, thinner walls, and slight woodiness. Soon the walls in this layer become mucilaginous; the

cells disintegrate along the plane of separation; the wind breaks off the leaf; and as this happens, or even before it, a layer of cork closes up the wound and makes a healing scar.

Apart from the wear and tear of the summer's industry, apart also from the great reduction of the available water-supply, there are waste-products which may become poisonous, and are also liable to clog the transporting tissues.

The fall of the leaves certainly helps to make the tree a singularly well-protected quiescent organism in winter. As evergreens show, the autumnal fall of the leaf is not necessary, but in ordinary cases it is very profitable, even life-saving.

A green leaf has two pigments which assist in the utilization of the red-orange-yellow rays of the sunlight and the splitting up of carbonic acid gas so that the oxygen is largely liberated and the carbon is retained to build up formaldehyde, sugar, and the like. These two invaluable pigments are called chlorophyll-*a* and chlorophyll-*b*, and they have an interesting chemical affinity with the oxygen-capturing red pigment (hæmoglobin) of our blood.

But along with the chlorophyll-greens there are two chlorophyll-yellows, belonging to the fatty series of pigments (lipochromes) that are familiar in shrimps and prawns and in the bright colouring-matter of carrots. When a leaf dies a contribution to the coloration is made by the disintegration of the chlorophylls and the lipochromes. Simple golden-yellows, as in ash-trees and willows, have this origin.

There seems no doubt that some useful results of the breaking down pass by the leaf-stalk into the branch, for it is a characteristic of the dying leaves that they surrender to the parent tree all that they can, so that they enrich it in their death as they have enriched it in their life.

When the separating partition is formed, transport from the leaf has to stop; but the fallen leaves contain little but waste. Their wonderful colouring may be appropriately called "beauty for ashes."

We may use the term "flower blue" as a translation of anthocyanin, to which is due the more vivid colouring of these flaming crimson maples and purple *Prunus*, besides brambles and sumacs in the undergrowth and the Virginian Creeper on the houses.

These anthocyanins or anthocyanes are usually dissolved in the cell sap, but they occur occasionally as crystals or grains. They are often present in petals, as in the blue of cornflowers and the orange of *Tropæolum*. They give apples their ruddy cheeks and rowan-berries their orange-red glamour. Sometimes, as in oaks, their colour-effect is helped by the presence of tannin.

Since anthocyan is a glucoside—that is to say, a combination of grape-sugar (glucose) with a tannin or something like it—there is naturally an abundant occurrence when there is a local accumulation of sugar, and this again is due to the lowering of the temperature in autumn.

It is difficult to believe that all this foliar gorgeousness, rivalling that of flowers, is of no use to the trees. Perhaps the anthocyan serves as a screen, absorbing the rays that may be injurious to the ferments still at work in the moribund leaf. Perhaps it absorbs rays that increase the temperature of the leaf and stave off death a little while longer. Perhaps, however, we are too keen to discover utilitarian justifications for beauty; it may be that the anthocyanes and the like have no great physiological significance, but merely represent a by-play in the leaf's graceful dying.

Why are some woods, like those of the St. Lawrence, so exceptionally beautiful in autumn?

It seems to be due to a happy combination of three factors—plenty of water, abundant sunshine, and yet a low temperature. These factors make the dying slow, giving time for the gradual disintegration of the greenish and yellowish pigments and an abundant formation of anthocyanins. It must also be noted that maples excel in sugar-making, and that supplies copious sugar to make glucosides.

WHAT CAUSES GALLS?

If anyone wishes a tough biological problem to work at, he should take up the study of galls. It will serve for the rest of his life, and it will certainly lengthen his days. The questions raised are so many and so interesting that they stimulate vitality. Galls are peculiar growths on plants which arise as answers-back to some intruding organism. The stimulus may be due to a fungus, as in the familiar case of Witches'-Brooms, or to a Nematode worm, as in the "ear-cockles" of wheat and the galls of millfoil and teasel, respectively due to three species of *Tylenchus*. Or small galls may be produced by mites. But the great majority of galls are answers-back to insects, and the finest are due to Hymenopterous gall-makers belonging to the family Cynipidæ, the familiar oak-apples furnishing a good example. But gall-makers also occur among the two-winged flies, bugs, and two or three other orders of insects. In this chapter we are speaking only of the galls connected with Hymenoptera, and we may keep in our mind as pictures the marble-galls and cushion-galls of oak-trees and the hairy Bedeguar tufts often seen on wild-rose bushes.

A gall may be formed on any part of a plant, from root to flower; but a particular gall-maker always keeps to a particular organ of the plant to which it is addicted. In most cases the gall is characteristic of its maker, so that we can often identify the insect without seeing it! In typical cases the mother-insect punctures the plant and inserts an egg in the growing tissue; when the egg hatches and the larva appears a gall begins to grow. In some galls made by saw-flies, the growth begins

before the egg is hatched; but this is exceptional. The usually accepted view is that secretions from the larva's salivary glands provoke the peculiar growth in the growing tissue of the plant; cells usually enlarge or multiply, but it is not at present clear why the new growth should be so specific and well-finished, or how the same plant, like an oak-tree, can produce several different kinds of galls in response to as many different gall-makers. It often surprises us to see a gall produced that is more or less out of keeping with the character of the normal plant, for there is surely something incongruous in a pubescent gall on an oak-tree or in a prickly gall on a smooth rose. But the puzzle increases when we scrutinize some of the galls of the oak-apple type and find definite nutritive layers, admirably suited for the gall-larva, but generous, to say the least, on the plant's part. Thus there may be an inner food-layer rich in proteins; then an outer food-layer rich in carbohydrates; and then a hard or corky protective rind, so protective that in some cases the gall remains fresh when the plant that made it is withering. And the touch of perfection is seen in galls where the nutritive cells are replaced by fresh growth when the larva has eaten them away. Such altruism, as one of the best known of plant ecologists says, seems to upset Darwinism! For it seemed to him that the plant was spending itself on behalf of an intruder which was nothing short of a nuisance. Apart from the shelters called domatia, which may encourage friendly mites whose waste-products and scavenger activities are possibly useful, it cannot be maintained that galls do the plants any good; and it is doubtful whether domatia are true galls. Subsidizing gall larvæ is like feeding an enemy, and this is too suicidal to be readily regarded as one of Nature's ways. Perhaps, however, the very perfection of the gall-structure is Darwinianly intelligible as a subtle imprison-

ment which keeps the intruder within a short radius, and lessens its possibilities of doing damage. Perhaps, however, the gall simply has to grow as it does in obedience to certain dimly understood *laws of growth*.

Some very interesting observations and experiments by Professor Werner Magnus have thrown fresh light on the dark problems of gall-production, and we shall state his general results. In gall-production there is always something in the way of a wound which exposes the plant-cells to new influences emanating from the intruder. The influence is not one that easily spreads; it is not readily diffusible.

Two chapters in gall-production should be distinguished, the first general and the second specific. In the first chapter there is nothing more than a multiplication or invigoration of already existing undifferentiated tissue; in the second chapter there is the development of something distinctly novel—a specific new growth. The first undifferentiated stage is induced in the saw-fly gall-makers by the wound inflicted by the mother-insect, and may be independent of the presence of the egg. A secretion from the mother-insect brings about a stronger development of the undifferentiated tissue of the plant.

In the Hymenopterous family of Chalcididæ, closely allied to the ordinary gall-flies or Cynipidæ, the first chapter may be induced either by the puncture made by the mother-insect or by wounds made by the newly hatched larva. Moreover, in a few cases there may be an exudation from the intruded egg.

In the gall-flies proper, or Cynipidæ, there may also be mechanical injuries due to the mother-insect or to the young larva; but the first chapter in gall-production is mainly due to a toxin, not readily diffusible, which proceeds from the opened egg or from the newly hatched larva. The result is a solution of the plant tissue, and

into a cradle of albuminoid material the intruder sinks! So much for chapter one.

The second stage, that of specific new growth, is induced in all Hymenopterous galls by the influence of the living and developing larva. It is not due to any introduction—once and for all—of a gall-virus. The presence of the living larva is essential, and it brings about changes, both positive and negative, in the influences that normally play upon the tissue of the plant; and the outcome is a specific neoplasm or gall.

The degeneration and solution of tissue that Magnus regards as characteristic of the first chapter in the typical "gall-fly" gall-production is due to a toxin produced by the newly hatched larva or by the developing egg. As regards the latter, the conclusion is borne out by Magnus's important experiments with injected extracts of the eggs of two of the common gall-flies—*Rhodites* and *Biorhiza*. There seems to be an "albumen-toxin," which brings about a sort of chemical wounding. Yet it may be unnecessary to assume any special "toxin," since it is well known that the introduction of foreign proteins into an organism is apt to be followed by disintegrative effects. In any case, some sort of disintegration occurs, and after the tissue-solution there is a development of mending or callus-tissue, as is common in plants after injury, as for instance in some of the leaves excavated by leaf-miners.

The point of Magnus's theory of the formation of specific galls is not any new discovery of a gall-making ferment or the like. What he emphasizes is the familiar fact that all growing depends on many regulative reactions and that a novel type of growing is to be expected when an intruder is in a position to play a part on the physiological stage. We know what happens when a fertilized mammalian ovum reaches its place in the wall of the

womb; it may not be the efficient cause of all that follows, but the changes would not have ensued if it had not found fixation. Its presence brings about changes in the previous routine—changes in stimulation and regulation—and the structural outcome is very advantageous. So it is with the gall-larva, to which the innocent plant responds almost as if it were part of itself, as is from a detached point of view the case. This is a promising outlook, and one wishes one had a new lease of life for experiment!

WHAT ARE CHIMÆRAS?

From ancient times fruit-growers have practised grafting and with great success. A common form of the device is to insert a shoot of some desirable tree into the stem—often lopped—of a sturdy one, taking care that the growing tissue and the young wood of the two plants are brought firmly together, so that genuine physiological fusion results. The engrafted bud or shoot is called the “scion” and it is made to combine with a “stock.” In this way a variety of fruit tree that is marked by great excellence can be quickly and surely multiplied, for the essential virtues of the scion are not affected by the vigour of the sturdy stock, except that its vegetative growth may be checked.

But this checking is an advantage when the object in view is to get much fruit. Thus we see orchards with the high-class engrafted young trees bearing very abundant and conveniently reachable fruit on the shoulders of the inconspicuous old-fashioned stocks. Scions and stock must be near relatives; thus the peach may be grafted on a plum stock, the apple on a pear, the pear on a quince, or the medlar on a hawthorn.

In modern times the grafting of succulent plants has been successfully effected, but most grafts are between trees. It is possible that the idea of grafting was suggested to the early fruit-growers by noticing that two branches of the same tree, or even of adjacent trees, sometimes fuse when they are so much rubbed together by the wind that two abraded surfaces are formed, and a mending of the mutual wounds results in a thoroughgoing fusion.

In some grafts the scion may be affected in a general

way by the stock, e.g. as regards time of flowering; and the stock may be invigorated by the growth of its nobler scion; but each retains its own characteristic features. There are, however, some puzzling cases of a different type, which suggest that there may be a mingling of the characters of scion and stock. In other words, there are alleged cases of "graft-hybrids"; and the most famous of these concerns the yellow and the purple laburnum. When a scion of the purple is engrafted on the yellow, the resulting growth or a cutting therefrom usually bears purple flowers, as a normal graft would do, but along with these there are others that are yellow.

"ADAM'S LABURNUM."—In some other ways the plant, which was called Adam's Laburnum (*Cytisus adami*), resembles both the yellow (*C. laburnum*) and the purple (*C. purpureus*) species; and Darwin called it a "graft-hybrid." It interested the great naturalist very much, and he speaks of "the extraordinary fact that two distinct species can unite by their cellular tissue, and subsequently produce a plant bearing leaves and sterile flowers intermediate in character between the scion and stock." But, as we shall explain later, it seems likely that Adam's Laburnum is even stranger than Darwin supposed.

A graft has been effected between the tomato (*Solanum lycopersicum*) and the Deadly Nightshade (*Solanum nigrum*), the technical names being useful to emphasize the fact that the two plants are species of one genus, *Solanum*, to which the potato also belongs. Now the shoots that grew from the artificially effected graft combined the characters of both stock and scion. Sometimes the result was more like a tomato, sometimes more like a nightshade, sometimes nearly intermediate between the two. So this looks like a graft-hybrid, and it received the name *Solanum tubigense*. It is not sterile as Adam's Laburnum is, and

its seedlings revert to one or other of the "parent" forms.

But some of the results of the grafting of tomato and nightshade are rather different from those we have mentioned, for part of the shoot is like the scion and part is like the stock. This is what is meant by a chimæra, two living creatures intimately combined, yet each retaining its intrinsic peculiarities.

Even when the result of a graft looks very like a blend, a minute analysis may show that there is a sort of patchwork combination of the two components. And if so, it is rather a chimæra than a graft-hybrid. In short, it is beginning to be doubtful whether there are any graft-hybrids at all.

Familiar in gardens and greenhouses are *Pelargoniums* with white-margined leaves, and some of these are due to grafting, and to vegetative propagation from the results of the graft. In this strange case one partner forms the main body of the plant, while the other forms the skin only or the skin plus the under-skin. This queer mosaic is a chimæra, and recent investigation has shown that Adam's Laburnum, whose secret we have been deferring, is another dual plant or chimæra, the main body being that of a yellow laburnum, while the skin is that of the purple species.

Homer's chimæra had the head of a lion, the body of a goat, and the tail of a dragon; and others were similarly impossible combinations. The zoologist's chimæra is a remarkable fish, sometimes caught off British coasts, which fishermen call the "shimmer"; and it probably owes its rightly spelled name to the impression that it is a sort of impossible combination of characters.

CHIMÆRAS AMONG ANIMALS.—But there are in the Animal Kingdom a few chimæras in the technical sense—

mosaics that man has made. Unfortunately, as regards impressiveness, they are mostly confined to early youth, and they are all very small when compared with Adam's Laburnum.

It is not very difficult to graft a piece of one animal on to another of a related species. Serious wounds have sometimes been mended in this way, and everyone knows of the transfusion of blood. There is nothing chimerical about this!

On the other hand, it is possible to graft together the very early stages of two different kinds of newt, with the result that they combine harmoniously and go on developing, each keeping to its own species! And just as in the plant world, so among these amphibians, the chimæras are of two kinds: (*a*) A region of the young animal, perhaps a whole side, may be of the one species, while another region or side may be as clearly of the other species. (*b*) In other cases, reminding one of the Pelargoniums, the skin belongs to the scion and the rest of the body to the stock. In both types of amphibian chimæra there is a combination, but not a mingling, of the two components. Another chimæra has been made by artificially combining two quite different species (or genera) of freshwater polyp, the stalked *Pelmatohydra* and the unstalked *Hydra*. They combine and flourish, but they do not mix.

IS THERE NATURAL "WIRELESS"?

Many have asked the question—certainly not a foolish one—whether there may be in Nature, apart from man's interference, any analogues of "wireless." For broadcasting purposes man generates, by artificial methods, electro-magnetic radiations of enormous wave-lengths which pass through space, or, as some say, form great ether-waves. But these electro-magnetic radiations are of the same general nature as the light-waves and the heat-waves that reach us from the sun; they all travel at the same velocity—186,300 miles per second; they differ in their wave-lengths. So the question comes to be: Are there electro-magnetic waves naturally produced to which living creatures, including of course man, are sensitive? And the first and very obvious part of the answer is that many living creatures besides ourselves are sensitive to the ordinary light-rays and heat-rays from the sun. Some expert students of ants maintain that certain of these high-strung little creatures are visually sensitive even to starlight. But the question opens out when we notice the modern confirmation of what Lord Avebury proved long ago, that ants can *see* ultra-violet rays, which are invisible to us though they exert a tonic influence on our health. Similarly there is no doubt that bees and some other insects are sensitive to ultra-violet rays. Thus, our first proposition is this, that where there is definite evidence of electro-magnetic waves, besides ordinary heat and light, being naturally present in the immediate environment of a living creature, there is no reason to deny the possibility of the living creature sensing these waves.

Another proposition may be safely ventured, that many living creatures are in certain directions far more sensitive than man. If we put into our mouth in front of our tongue a copper and a silver coin there is a slight electric discharge whenever the two coins touch. We notice a slightly acid taste. To a weak discharge of this kind the Hindu student is twice as sensitive as a European, but a common weed called *Biophytum* is four times more sensitive than the Hindu!

Man can make an instrument so sensitive to slight changes in temperature that it records the fact that someone opened a shutter in the door of the room and thrust in his warm hand; but there are many cases among living creatures of similar sensitiveness to changes in electro-magnetic vibrations. Sir Jagadis Chunder Bose, who has done such brilliant work in demonstrating the sensitiveness of many ordinary plants, records that when he was studying one day the response that a plant made to slight changes in illumination he observed a sudden change in reactivity for which he could find no laboratory cause. But on looking through the window he noticed that a wisp of cloud was passing across the sun! A bat seems to sense an obstacle before it touches it, and in a dark room criss-crossed with taut wires it will fly to and fro without touching any, as the absence of audible vibration proves. Or, passing to mechanical stimuli, we know that an earthworm can detect the slight vibrations of the soil produced by the light footsteps of the thrush or blackbird. So our second point is that we must be careful not to rule out a hypothesis of animal sensitiveness to physical stimuli on the ground that these are too delicate to be perceived. Man has no conception of the spider's delicacy of touch, or of the honey-bee's delicacy of smell. His range of sensitiveness is probably greatest of all, but along any one line he may be surpassed.

Our third proposition is that there are among living creatures various puzzling phenomena which may perhaps become less enigmatical if we allow the possibility of unusual sensitiveness to electro-magnetic radiations in space. Among these puzzling phenomena the most familiar is the way-finding exhibited by migratory birds. As already mentioned it has been proved that some species of terns or sea-swallows transported from their nests in hooded cages on board ship, into regions outside their migrational range, are in some cases able to find their way home in a few hours or days, according to the distance. We may profitably separate this from the way-finding of ants and bees when they turn their face homewards, for the insect's finding of its way is usually explicable in terms of enregistered experience of visual, tactile, and olfactory way-posts, and also in terms of kinæsthesia, or enregistration of muscular movements. But this theory of individual apprenticeship to cues does not throw much light on the fact that young swallows succeed in many cases in migrating from Britain to Africa, or on the fact that a young swallow, marked with an aluminium ring on its foot in an Aberdeenshire farmstead, has been known to return from Africa to its birthplace the following year. Even when much is put to the credit of (*a*) social tradition—those birds leading well in 1930 who followed well in 1928 and 1929—(*b*) unrecorded tentative explorations in the air such as are suggested by the behaviour of carrier pigeons, and (*c*) the acute and extensive vision exhibited by birds, many naturalists are inclined to think that there must be sensory cues of a subtler sort, and one of the suggestions is that birds are sensitive to differences in terrestrial magnetism—a view that seems to have found some favour with Lord Kelvin. Every locality has its characteristic magnetic features ("declination" and "dip"),

and the hypothesis is that migrating birds and carrier pigeons seek out the magnetic conditions that they are accustomed to in their home or homes. All we are here concerned with is that this possibility is not to be pooh-poohed as absurd. But there are obvious difficulties. Thus (1) the "magnetic sense" has not been *proved* for any bird or for any other animal; (2) the homing of swallows from a great distance would, on the hypothesis suggested, imply sensitive appreciation of a succession of very complex magnetic diversities; and (3) "the capacity for perceiving magnetic directions would by itself be no more serviceable to a migrant than would a compass to a human being not also possessed of a map or at least of a mental picture of the country to be traversed. The magnetic indications must not only be perceived but must also be brought into due relation with the essential geographical facts." (A. L. Thomson, *Problems of Bird Migration*, 1926.)

While the magnetic sense of birds remains a mere hypothesis until it is proved experimentally that they are sensitive to changes in the magnetic condition of their environment, there is no absurdity in the supposition; and here it should be noticed that many creatures have sensory structures whose precise function is uncertain, while others show a surprising sensitiveness to such influences as impending changes of weather, although we cannot say precisely how they are affected.

There is in some cases a remarkable sensitiveness to the phases of the moon, more, it seems, than can be readily accounted for by a correlation with the highest and lowest tides. The Atlantic Palolo worm at Tortugas spawns by breaking off the posterior part of its long narrow body, and it does this punctually within three days of the moon's last quarter between June 29 and July 28. The Pacific Palolo at Fiji and Samoa does the

same at full moon in October or November. The Californian smelts, called grunions, wriggle out on the sandy beaches exactly at high tide on the second, third, and fourth nights after the highest tides in spring, usually in April. The little green *Convoluta* worms of the flat beach at Roscoff come up whenever the tide goes out, and sink into the sand again at the first splash of the returning flow; and they will continue doing this at the appropriate time for a week when transferred to the tideless aquarium of the laboratory. Of course, the problem in this and in many other cases is complicated by the establishment of a bodily rhythm to which the environmental change is only the trigger-puller.

If the young Loggerhead Turtle, just hatched out of the egg, be placed in a deep tub, it moves in all directions tentatively. But if it is placed on the bare sand in which the eggs were laid, or on the tub turned upside down, it moves towards the sea. It is constitutionally wound up to do so, and Parker's careful experiments have proved that while it has a constitutional preference for blue colour and for going down a slope rather than up, its main inborn bias is to move towards the more open horizon—which usually means the sea.

It is unprofitable to consider telepathy *in this connection*, for to bring it in here would imply a mixing up of two sets of formulæ. We have been discussing the sensory discrimination of electro-magnetic vibrations, such as those of "wireless," but telepathy means the immediate affection of one *mind* by another *mind*, and *not* by means of the sense-organs. Moreover, apart from electric fishes and luminous creatures, no organism is known to give off radiations.

But in connection with unusual susceptibilities it would also be useful to enquire into cases of human hyper-æsthesia, i.e. of exaggerated sensitiveness to sensory

stimuli, which *might possibly be* electro-magnetic. Here should be considered, for instance, the alleged hyper-æsthesia of "dowsers" and metal-finders. But this cannot be shortly dealt with. Of even greater interest is the possible stimulation of living creatures by the small amount of Gamma radiation present in Nature. Perhaps there is enough to serve as a trigger-puller to new departures or variations—the raw materials of possible evolution. So our final proposition is that we must be careful not to close the door on the suggestion that living creatures may be influenced by electro-magnetic radiations in Nature, besides those of ordinary light-waves and heat-waves.

NATURAL HISTORY CREDULITIES

A man may be a senior wrangler, so to speak, and yet not know how many teeth he has, or ought to have, Very few people know where their thyroid gland is, though it is one of the most important organs in the body, but everyone knows that every particle of the body changes every seven years. This is what is meant by a credulity—almost universally accepted and yet a nonsensical guess.

In a way the biggest fact about a living body is that it is always changing. It is continually breaking down and almost as continually being built up again. Its emblem is the Burning Bush of old, always aflame yet not consumed. To change the metaphor violently, the living body is like an eddy or whirlpool in a stream; its materials are ceaselessly changing, yet the form remains much the same year after year. Some tissues, like bone, change slowly after growing stops; others, like those of the liver, the seat of bustling activity, change very rapidly.

We do not get any new nerve-cells after we are born, but the substance of the active grey matter of the brain must be in process of continual recuperation. Our red blood corpuscles have a relatively short life; they get worn out; they are scrapped; they are replaced.

What, then, is the credulity? It is in fixing the time of replacement at seven years. There is no warrant for this arbitrary estimate, which was doubtless based on the fact that seven is the perfect number.

Some of our common credulities refer to the supposed susceptibility of our body to certain influences; and a good example is the widespread belief that drinking salt water brings on madness. For subtle physiological

reasons, concerned in part with the density of the living matter and the diffusion of fluid material from cell to cell, the health of the body depends on a delicate balance between the inorganic salts in the blood. If there should be a lack of salts in the food, things may go badly wrong; and similarly if through lack of fresh water or its equivalents there should be an accumulation of salts in the blood, everything goes wrong in the working of the body, and delirium is likely to set in.

For lack of fresh water the shipwrecked mariners are already poisoned or delirious; a draught from the sea is simply the final push towards death.

By several physiologists, Macallum in particular, attention has been directed to the similarity between the proportions of salts in our (or vertebrate) blood and the proportions of the same salts in sea-water. There is an extraordinary resemblance, especially in the proportions of potassium and sodium to calcium, between the blood fluid of backboned animals and the sea; and this resemblance is increased when allowance is made for the change in the sea-water since terrestrial animals began to emerge hundreds of millions of years ago.

"When vertebrates with a closed circulatory system took to land, they took with them a blood of the same composition, as regards salt, as the sea-water which they left behind."

We are not suggesting that a drink from the ocean is like going back to old times, but it is a fact that sea-water, *diluted to the same osmotic pressure as the blood*, is a very effective physiological solution!

Another credulity which is very widespread is the notion that the moon can exert some baneful influence on man's mind. This is expressed, of course, in the word "lunatic," and is perhaps suggested in our description of an unfounded hypothesis as "all moonshine." There is no warrant what-

ever for supposing that anyone can be injured by walking or resting barcheaded in the moonlight, when "the whole air whitens with a boundless tide of silver radiance."

After all, moonlight is simply reflected sunlight, and gentle at that. It is perhaps excusable to speak of sunstroke when the heart or the nervous system gives way under the strain of a very hot summer, though there is many a sunstroke that has more to do with clothes, stuffy rooms, and "habits" than with sunshine. But there is no possibility of becoming moonstruck. We might go farther and say that the moon has no influence on the weather, but we are positively afraid of the remonstrances that would be evoked by such an upsetting statement.

The class of mammals includes (1) the duckmole and the spiny ant-eater, both of which lay eggs, strange to say; and (2) the sub-class of marsupials, such as the kangaroos and opossums, whose young are born very prematurely, unable even to suck; and (3) all the other ordinary furred quadrupeds, in which the unborn offspring is carried for a longer or shorter time in intimate physiological partnership with its mother. A mare carries her foal for eleven months, and during that period there is a constant opportunity, through the intricate linkage called the placenta, for give and take between the two partners.

The health of the mother, both bodily and mental, has a profound influence on the unborn offspring. In addition to the diffusion of food and oxygen and the like, there are subtler influences which a great authority once called "the wireless telegraphy of antenatal life." But, to come to the point, there seems to be no scientific basis for the credulous idea that particular sights which strongly impressed the mother can have any specific effect on the developing offspring.

We know, indeed, of strange coincidences, but we also know that malformations similar to those that are misinterpreted in mankind occur in the hen-house; and no one will persuade us that the shocked brooding fowl can specifically influence her offspring within the egg in terms of a particularly vivid maternal impression.

We are not forgetting the sharp practice by which the patriarch Jacob tried to influence the colour of his cattle by letting them gaze on peeled rods, but breeders even of to-day are not always averse to letting some nimbus of the magical gather round their achievements.

To see beautiful things is always to the good, and the sight of ugly things is always to be avoided if possible; but the idea that a shocking sight witnessed by a mother can leave its definitive mark on her unborn child is a credulity which should be buried deep.

NATURAL HISTORY INVOLVED IN EVERYDAY
CONVERSATION

It has often been pointed out that the Bible has taken (who can wonder?) a very firm grip of the current English language. Many people continually use Biblical phrases without being aware that they are quoting scripture. To some extent this unconscious quotation holds also in regard to the English Prayer Book; but among the engaging young people of present-day Scotland, born in the first decade of the century, we cannot, we regret to say, detect almost any phrases reminiscent of the Shorter Catechism! In everyday speech one often hears quotations from the poets, but we are thinking at present of tags and phrases that have been unconsciously incorporated into conversation, and our impression is that the authors to whom the majority of these are due are Shakespeare and Dickens.

What we wish to do, however, is to illustrate the extent to which Natural History has interpenetrated ordinary conversation. In the first place there are some animals with a feature so pronounced that we hit the nail on the head conversationally when we apply that animal's name appositely to a man or woman. What an ass, the big donkey, what a cat, you giddy goat, what a shrew, the skunk, what a sponge he was! This is to be distinguished from the old custom of giving an animal's name to a child (thus Deborah means "bee"), or from the still persistent custom of giving an animal's name colloquially to a man. Thus we have heard of men who went by the name of "crab," "spider," and "weasel." A common name like Todd probably means "fox" in Scotland.

In the second place, we often make an effective adjective of an animal's name—a very fishy business, a waspish disposition, what elephantine humour, quite kittenish she was, mulish was the only word for him, badly hen-pecked poor man.

Sometimes, thirdly, the reference is not to the man or woman as a whole, but to some particular quality. Thus we speak of his eagle eye, his horse-sense, his power of working like a horse, or of holding on to his victim like a horse-leech, the way he kept as close as an oyster, his quickness to make a "bee-line" for home.

Some of the comparisons, in the fourth place, where the animal is named, are so apt that our language would lose no small part of its picturesqueness if they disappeared—as slippery as an eel, a mere fleabite, as proud as a peacock, as busy as a bee, going at a snail's pace, a fish out of water, he never turned a hair, she lived a butterfly existence, he was as greedy as a cormorant, they lived a cat and dog life together. Sometimes the point has become blunt. Thus, while we understand as merry as a cricket, we are not so clear in regard to as merry as a grig—a grig being a lamprey. Sometimes the quality referred to in the animal expresses a quite conventional estimate; thus a badger is neither surly nor foul; neither goose nor donkey can be called a stupid creature. As blind as a bat could only apply to the diurnal life; as blind as a mole is much better from the Natural History point of view, for there is no likelihood that the mole's minute arrested eye can form a clear-cut image. The common contemptuous reference to "the brains of a hen" requires a saving clause.

In the fifth place, there are a few very effective verbs—he "wolfed" down his food; he is the man to "ferret" it out for you; he "jackalled" for his lion; there is no doubt that he "ratted." Sixthly, the comparison tells

because it calls up a vivid, often a pleasant picture. A bird in the hand is worth two in the bush; first catch your hare; if you chase two hares you will catch neither; the hare starts when man least expects it; it's a sairy mouse that hath but ae holt; it is better to be the head of a lizard than the tail of a lion; a beetle in dung thinks himself a king; the owl thinks all her young ones beauties; the wolf is at the door; there's a fly in the ointment and another on the wheel; put not all your eggs in one basket nor all your bells on one horse; burn not your house to frighten away the mice; take not a musket to kill a butterfly; do not make a mountain of a mole-hill; give a dog a bad name and his work is done; many a lame dog did that man help over a stile.

Seventhly, there may be a biological generalization couched in simple reference to particular living creatures. You do not gather grapes off thistles. You cannot make a silk purse out of a sow's ear. Of a pig's tail you cannot make a horn. An emmet may work its heart out, but can never make honey (unless it happens to be a honey ant!). A wild goose never laid a tame egg. He that sows thistles shall reap prickles. There were tares amongst the wheat. Birds of a feather flock together. He took to evil ways as a duckling takes to water.

An eighth group includes sayings in which the Natural History is surprisingly good. The cat's automatic power of righting itself during a tumble from a height has been much studied by physiologists, and is referred to in the phrase, "falling on his feet," as also in the cat's "nine lives." As cute as a 'possum refers to the well-known death-feigning. Even a worm will turn—for instance, on a centipede. The early bird gets the belated worm—that stayed out too long. It's an ill bird that files its own nest—for the instinct of cleanliness is highly developed in most. Bees that have honey in their mouths have stings in their

tails—thus drones have neither. Truths and roses usually have thorns. Don't count your chickens before they are hatched.

We must keep a ninth division for those references which imply out-of-date Natural History, or something superstitious, or some puzzle. To take the last first, why do people speak of it "raining cats and dogs"? We can understand it raining tadpoles and minnows, blood-worms and sulphur, but a shower of cats and dogs is puzzling. Sometimes the background zoology is a little out of date, yet how sorry we should be to part with the eagle that renews its youth; the phoenix that rises from its own ashes; the crocodile shedding piteous tears to beguile the tender-hearted; the lions roaring after their prey (the uproariousness being normally post-prandial in Wild Nature); the deaf adder that stoppeth her ear, though there is no opening to stop; the ostrich that sticks its head into a bush to avoid being seen.

One of the hawkmoths has been watched paying a hundred visits in five minutes to the blossoms of *Viola calcarata*; what a beautiful picture of "flying visits," but we require some explanation of Shakespeare's statement that the owl was the baker's daughter. The familiar statement that the robin and the wren are God's cock and hen expresses the widespread error that these two birds are male and female of the same species, yet it is a pleasant superstition. In all these cases we must take the fat with the lean. Pigeon's milk is a reality; a mare's nest is a fiction—peculiarly apposite because the newborn foal staggers along so quickly after its mother.

Our tenth group is for adages of the proverb type, where the Natural History references are simply aids to vividness. The last straw breaks the camel's back; one scabbed sheep is enough to spoil a flock; kill not the goose that lays the golden eggs; the raven said to the rook,

"Stand away, Black Cat"; nightingale and cuckoo sing both in one month; one swallow does not make a summer; all his geese were swans; he nourished a snake in his bosom; a lion's skin is never cheap; as well be hung for a sheep as for a lamb; one man may bring his horse to water, but ten cannot make him drink; habits are at first cobwebs, then cables; once bitten, twice shy; even an ass will not fall twice into the same quicksand; kill the cockatrice while still in the egg; curses, like chickens, come home to roost; give him a hair of the dog that bit him, and let the coward cat of a lion's heart (see *Modern Medicine, Triumphs of*); great cry, but little wool; do not let the cat out of the bag, for no one can tell how it will jump; what is sauce for the goose is sauce for the gander (see *Justice, Sense of*).

These few instances of the interpenetration of Natural History into ordinary speech must suffice. Yet we are reminded of one more, that a man with a hobby is like a dog with a bone; even if it is buried he will be at it again. We feel sure that we shall have to return to this subject.

PART III

CHAPTER XL

DO ANIMALS THINK?

One of the overworked words in our language is "instinctive," the varied use of which is bound to raise puzzles in every thoughtful mind.

When a spider makes a web of a particular pattern true to type the very first time it tries, the naturalist calls this instinctive behaviour, which is the right and proper usage. But something very different is implied when we say that our repugnance to a particular proposal is "instinctive."

During an air raid a distinguished physician was seen to run quickly along the street, and when he was afterwards asked why he did this he answered, "I cannot tell; it was purely instinctive." This may be a defensible use of the word, but we mean something very different when we say that making a honeycomb is instinctive to the hive-bee, for that means a definite engrained capacity for going through a routine that leads to a singularly effective result.

Two men were walking along the towpath of a canal; the heavier of the two slipped over the edge; his companion instantly gripped his arm, trying to save him; and the result was that both found themselves in the water. In afterwards apologizing for his gentlemanly but mistaken kindness the lighter of the men said:

I didn't think; I did it quite instinctively; I now see that it would have been not only more intelligent, but in actual fact kinder, if I had just let him slip in, for then by sitting down hard on the bank I might have easily helped him to get out.

What the would-be rescuer did was *impulsive*, and it was probably an indication of a friendly disposition and a

deep-down sympathy. But it should not be called instinctive, unless we simply use that word to mean that the action was not deliberate or thought out, an idea that is indicated not so badly by the word "impulsive."

In many cases the impulsive clutch or grip is the outcome of habituation; it implies long experience of similar situations, in looking after children or novices for instance. The pupil who is being taught to ride a push-bicycle, or sail a boat, or drive a motor-car, sometimes expresses amazement at the deft way in which the instructor anticipates a casualty. "He seems to know instinctively what to do," it is said; but it is a pity to overwork this word so badly. The instructor saves the situation in the nick of time, but it is because he knows all the possibilities of danger and the best ways of avoiding it. His seemingly automatic action is an expression of habituation and experience; it should not be called instinctive.

It is on record that a cat whose fur had been set on fire ran a few yards and plunged into a trough of water. This was either a flash of intelligence, as we are inclined to think, or a fortuitous act of despair. When an unexploded bomb landed on a ship's deck in the midst of a civilian company there was a flash of clear intelligence when an ignoramus threw it swiftly into the sea. This did not indicate anything instinctive; it showed a rapidly working intelligence. When an unskilled person has thrown an incandescent overheated body into a tub of water the results have been disastrous.

What was wrong in the last case was merely that the quick-working intelligence of the man with the presence of mind had not a sufficiently wide and clear scientific background. He did not know that an explosion would follow. But our point is simply that the valuable word instinctive should not be blunted and spoiled by application to entirely different kinds of behaviour, such as

those springing from a very rapidly working intelligence that "appreciates the situation" and acts like lightning accordingly. If the scientific basis is inadequate then the result is quite likely to be a fiasco.

And here we must take the opportunity of saying that no small part of science consists in resolutely saying, "If this, then that," and in verifying this assertion against all-comers. If we examine ourselves frankly, we shall find that it is only in a small percentage of our assertions that we are quite confident in saying, "If this, then that." We say a certain change in the moon means a change in the weather; but this is much worse than moonshine. Yet our beliefs are full of such things.

Let us consider what the naturalist means by "instinctive."

When we draw our finger quickly away from a hot cinder, that is a reflex action, requiring neither intelligence nor will; and the animal world abounds in instances of these reflexes, which are technically called "unconditioned." This word is used to distinguish them from "conditioned" reflexes, which are established in the course of individual experience. Thus when a whistle is sounded whenever a dog is shown the bone he is to get, the dog comes to link together the whistle and the meal, and does so in such a close way that his mouth will water when the whistle is sounded. That the saliva in the dog's mouth should flow when he sees the bone is an *unconditioned* reflex, but that the whistle alone should evoke the flow is an illustration of a *conditioned* reflex, and of this kind of behaviour there are many instances among animals, and also in ourselves. An associated more or less arbitrary stimulus works like the original real one.

In many cases a reflex action is all at once over and done with, but it is sometimes a link in a chain. When the mother eagle touches the very young nestling's bill with

a piece of torn flesh, the youngster immediately opens its mouth and gapes. Then it grips with its bill and with the muscular pharynx at the back of the mouth. Then it gulps and swallows. Without following the food farther down we see at once a chain of at least three links. If we suppose a much longer chain, each link bringing the next one into activity, we begin to get near the physiological side of instinctive behaviour. The animal world is rich in examples of instinctive chains, which have perhaps evolved out of reflex chains.

Let us take the case of the *Yucca* moth which pollinates the *Yucca* flowers. After she has emerged from the cocoon into a world of which she previously had had no more than a caterpillar's experience, and after she has encountered a mate in her short flight, she proceeds to visit the freshly opened blossom of a *Yucca* plant. Seeking nectar, she plunges her proboscis into the depth of the bell, and gets her head well dusted with pollen from the stamens. This fertilizing dust she tidies into a little ball, which sticks out on the front of her head.

Then she proceeds to visit an older blossom, in the seedbox of which she lays her eggs, at the same time depositing the ball of pollen on the viscid tip of the pistil. From the pollen grains grow down the pollen tubes, and a male nucleus eventually reaches the egg-cell within the embryo sac, within the ovule, within the ovary. This means fertilization. The sequence is profitable for the race of *Yucca* moths, for the hidden eggs hatch into caterpillars, which feed on a number of seeds. It is profitable also for the *Yucca* plant, for the fertilization of the egg-cells is secured, and there are plenty of uninjured seeds left to continue the race.

Here, then, is a chain of effective acts on the *Yucca* moth's part, and this is what the naturalist means by a chain-instinct. In some cases the chain may be described

as a succession of reflex acts, each hereditarily fixed, one link leading on to another; in other cases the purely physiological description does not seem to make good sense by itself, and it seems necessary to suppose that the behaviour is suffused with awareness and backed by endeavour. This is strongly suggested when the animal is able to adjust its behaviour to slightly novel circumstances.

When a ewe is going to give birth to a lamb she instinctively seeks to separate herself from the flock, and may force a way through a hedge into a quiet field. Secondly, she often scrapes on the ground with her forefeet, an instinctive echo of the custom wild sheep have of making a comfortable bed in the rough herbage. On most British pastures it is no longer of any use, for there is an abundance of suitable places.

When the ewe has given birth to her lamb she naturally turns her head to lick with her tongue, and this is very important, for sensing the odour and taste about the newborn lamb is the almost necessary condition of the maternal care that follows. When the mother is having a lamb for the first time she is sometimes startled at its appearance, and may take fright altogether. But once she has a taste and smell of her offspring all is well. The maternal instincts are liberated, and the devotion cannot be too much admired. But our special point is that the instinctive acts are links in a chain, and strange things often happen when something disturbs the usual sequence. Thus, if a ewe that has not actually brought forth her own lamb happens to lick another newly borne by a neighbour, her maternal instinct may burst forth and she may steal the lamb, to the serious detriment of her own when it comes to be born.

From such cases we get some glimpse of the deep difference between instinctive behaviour and that which we

call intelligent, meaning that it requires to be individually learned in the light of some understanding of the situation. Thus, the collie dog is often intelligent in its shepherding of the sheep, though the influence of training by its mother and by its master must always be allowed for in estimating its actual understanding.

When do we call an animal's behaviour instinctive and when intelligent? This deep question requires a long answer, but part of the answer is this: Intelligent behaviour requires an apprenticeship; it is not the expression of a ready-made inborn capacity, it is the outcome of learning. And it is not every kind of learning that avails; it must be learning that includes some perception of the relation of things. An animal may be trained to do an apparently very clever thing, and yet this need not imply much intelligence. The fact is that intelligent behaviour is controlled by some measure of understanding, some putting two and two together, some spice of judgment. It is not possible to describe a truly intelligent action without assuming that the creature has made use of some sort of inference, a sort of picture-logic.

When a chimpanzee fastens a short bamboo rod into the hollow end of a long one so as to reach a desired fruit outside its cage, that is intelligence. When it piles one box on the top of another to the number of four so as to reach a banana hanging from the roof, that is intelligence. There is some mastery of a new situation, some adjustment of old ways to new ends, some control of actions in reference to a perceived solution, which probably takes the form of a mental picture.

But, generous as we are inclined to be, we cannot say that animals ever attain to any high level of intelligent behaviour. Their masterpieces on the instinctive line of evolution are relatively more striking than the best they can do on the intelligent line. A child of three could give

points to any anthropoid ape in the intelligent solution of a practical problem, but no child of three could attain to the manipulative skill implied in the web of a garden spider.

Which is the more admirable, instinct or intelligence? is one of the many unfair questions, like which is better—co-operation or competition, mutual aid or each for himself? Each has its peculiar advantages, each has its defects and dangers. For certain purposes co-operative endeavour is the more effective, for other purposes individual efforts are more likely to succeed. If a man got a livelihood after the manner of a web-spinning spider, he would not be likely to be social; if he were a Lilliputian ant he would not be likely to advocate a solitary struggle.

So instinctive behaviour has certain advantages and intelligent behaviour has others; and both have their drawbacks. They are on different lines of evolution, and they are centred in different kinds of brains.

When an animal lives a short life with much routine, the same thing happening over and over again, instinctive behaviour works well. This is particularly true when the life-history is of such a nature that the animal on reaching a certain stage is suddenly plunged into a novel set of circumstances. There is no time now for apprenticeship, and thus the value of instinct is that a complicated series of operations, such as are involved in making a wasp's nest or a spider's web, is undertaken without hesitation, and carried out without mistake the very first time. The drawback is that even a slight disturbance of the routine is apt to nonplus the creature hopelessly, unless it has some plastic intelligence on which to fall back. We are not saying that all instincts are devoid of plasticity, but that is the chief drawback of the majority. As intelligence implies some appreciation of the relations of things, it can adjust actions to suit particular cases. The

drawback is that its effectiveness is not ready-made; it has to be learned.

Many lovers of animals are wont to say to the naturalist :

You are far too niggardly: you say a wasp is a creature predominantly instinctive, but I have seen one act in a most intelligent way, sawing off the wings and lower legs of a captured insect which it was unable to carry through the air; or stinging a troublesome captive in a nerve centre so that it was instantaneously paralysed.

The answer to that is that many predominantly instinctive animals have flashes of intelligence, and that many apparently clever operations exhibited by a particular kind of wasp, let us say, turn out to be part of the hereditary stock which all members of that species possess. Similarly, when the proud owner of an intelligent fox terrier says that he is as sure of his dog's reason as he is of his own, the answer is that the word "reason" is used by experts in a quite definite way to indicate the power of working with general ideas. Many an animal shows reasoning; none that we know of shows reason.

There is as yet no convincing evidence that even the most intelligent animals, such as dogs, horses, elephants, and apes, ever behave in such a way that the observer is forced to credit them with making mental experiments with general ideas. This is man's prerogative, and it is only sometimes that he uses his power. Much of his behaviour is intelligent; he has a few general instincts; and he has a fair equipment of reflexes. A famous expert on ants, Professor Forel, once estimated that about one per cent. of an ant's activities is intelligent, but that about forty per cent. of man's is intelligent or rational. When an ordinary person says that his dog certainly has reason he probably means that it can reason, or make an inference; but that would come within the range of intelligence.

When we are commending a youth we sometimes say that he has "good instincts." What do we mean? Man

has a few rather generalized instincts, such as the self-preservative instinct, the social instinct, but he has few instincts of the precise detailed type that the naturalist admires in bees, and to some extent in birds, where they are often mingled with intelligence. What, then, do we mean when we say of a youth that he has good instincts—one of the best of gifts?

We mean that he is hereditarily endowed with wholesome springs of conduct, for there is such a thing as being born honourable, as there is such a thing as being born shifty. Members of a fine family often have inborn springs of conduct, continued through generations, and it is to these that we often refer when we speak of good instincts. The impulses toward conduct are in the direction of what is straight and noble and of good report. And there is some momentum in them, the hereditary momentum of generations of good breeding. It was said of Clerk-Maxwell that he *could not* make a geometrical error; it was said of a distinguished French scholar that he *could not* be discourteous, even to a dog. Some of these deeply ingrained predispositions toward fineness, whether of intellect or of character, are the most precious legacies that can be racially entailed.

But by good instincts we sometimes mean that the youth has *habituated* himself to being straight and clean and clear. He has developed a conscience that tends to keep him in line with what man at his best has always regarded as best—the true, the beautiful, and the good. A ready sensitiveness to the social embodiments and traditions of morals is part of the instinctive bias toward rightness rather than wrongness. No doubt man is a free agent and prone to err, but it must be recognized that the momentum of human evolution, both in the organism and in the permanent products of society, is on the whole stronger toward goodness, truth, and beauty than

toward badness, falseness, and ugliness. For evolution has been on the whole *integrative*; and in the realm of organisms and in the kingdom of Man what makes for integration is therefore stronger than what makes for disintegration. Health *must* be more persistent than disease; truth *must* be more lasting than error; goodness *must* triumph over evil.

There is yet another sense in which we use the word "instinctive." We use it as a synonym for the intuitive—that mysterious quality which some doctors, for instance, show in immediately recognizing what is wrong; which some men show in immediately recognizing how to turn at a moral forking of the ways.

DO ANIMALS EVER USE TOOLS?

We have seen chimpanzees washing the shelves of their cupboard with a cloth, and wringing it, but we do not know how much of their performance was simply imitation. It was interesting, however, for it was getting near the using of a tool. Occasionally a monkey in a cage will use a bent stick to draw something towards it, and there are stories of monkeys pelting intruders with stones. A good case of an animal using a tool would be a convincing example of intelligence if it could be shown to be independent of imitation or education—if the animal did it off its own bat, so to speak.

As there is no doubt that many animals are intelligent there is point in the question: Why are examples of tool-using so far to seek? Part of the answer is that many animals follow a beaten track, the needs of which are quite well met by their bodily equipment of fingers and toes, lips and snout, beak and talons. A honey-bee manipulates wax, for instance, but it needs no tool; its first pair of mouth-parts serve admirably. With the same instruments the leaf-cutting bee cuts neat semicircles off the rose leaves, and uses them to line its nest. It was a wise man who said animals have tools which are parts of themselves; man's tools are disconnected extensions of his limbs.

What should we say of the thrush hammering the snails' shells on a stone until it breaks them? Is not the stone a tool in this case, though it is neither movable nor fashioned? But we know of a better example. There is a digger-wasp which stores caterpillars in the underground burrow where the eggs are laid. The stung and thus paralysed

caterpillars serve as food for the wasp-grubs when these are hatched. When it has deposited a caterpillar in the burrow, and comes out again to seek for another, the digger-wasp quickly closes up the entrance. When the store is complete, the entrance is closed up with great care, the earth is pressed firm, and it is often made quite like the surroundings. What Mrs. Peckham saw some years ago in this connection is of great interest to us just now. She saw a wasp in finishing off its work take a tiny pebble in its mouth and use this to beat the earth level over the entrance to the burrow. Surely this was using a tool and it would be of value to try to find other examples. Probably however, it will turn out that man stands alone in using tools which he himself has fashioned.

To what we have said as to tools, let us add a note on the way some animals utilize other animals as guests. It is well known that some kinds of ants keep little beetles as guests or pets, somewhat as man gives hospitality to dogs and cats and canaries. In some cases the beetles or their grubs exude juice of which the ants are very fond. This exudation may actually be blood, laden with nutrient material, or it may be a secretion from skin-glands. There is much, however, that is perplexing about these beetle-guests, and we wish to refer to a particularly difficult case studied by Father Wasmann, a famous entomologist. It concerns a little beetle that lives in the colonies of the red ant. From the hairs of the full-grown beetle the ants lick off an apparently pleasant secretion, and from the larval beetles a palatable substance exudes. The ants feed the beetles and tend their young; the beetles have a curious way of begging food when they are hungry, yet they will give back some of it if an ant is pressing. The relations seem very friendly, but there is a skeleton in the cupboard. The difficulty is that the larval beetles do a great deal of harm, for they devour the grubs

of the ants. Sometimes, furthermore, in a way that is not clear, the guests seem to bring about the development of abnormal and practically useless ants, a sort of "half-and-between stage," intermediate between females and workers.

Now Father Wasmann tells us that the greater part of the ants' brood is sometimes destroyed by the beetle-guests, and the pernicious association would doubtless have come to an end long ago by the death of all the ants had it not been for a very interesting check, which offers a fine illustration of the subtlety of the ways of life. The red ants have the habit of burying the grubs belonging to the colony when the time comes for them to pass into the next chapter of their life-history—the pupa stage. After the ant-grubs have spun their cocoons, or pupal robes, beneath the ground and rested a little, the workers dig them up again and clean them. But the beetle-grubs are not very unlike the ant-grubs, and the workers seem to treat them both in the same way. The beetle-grubs are buried in the ground, and unearched again after a short time. Now this mode of treatment, which seems very suitable for the ant-pupa, is fatal to the beetle-pupa. In fact, none hatch except those that have been overlooked and left in the ground. Thus, the dangerous guest-beetle is kept in check.

It has been maintained by Professor W. M. Wheeler that the whole ant community is based on the principle of "nutritive exchange," the simplest expression of which is seen when the larvæ, on being fed by their mothers or nurses, give something back in the way of salivary juice or nutritive secretion. It may be that red ants, in their puzzling linkage with the dangerous beetle who abuses their hospitality, are just illustrating a custom widespread among their kin—namely, the establishment of "nutritive exchanges." And, if it be said that an experi-

ment so dangerous could not be persisted in for long, we have to bring forward a fact which makes the riddle almost disappear. Careful enquiries seem to show that it is only in certain regions that the beetle is a common visitor in the ants' community.

IS TELEPATHY A FACT?

The word "telepathy" (feeling from a distance) was invented by Myers in 1882 to denote "the communication of impressions of any kind from one mind to another, independent of the recognized channels of sense"; and the typical phenomena concern two living people, an "agent" and a "percipient" (also called "recipient"), the latter appearing to receive some novel information from the former. Thus the recipient may tell the experimenter what the agent (of course, unseen, unheard, and out of touch) was thinking intently about, the subject being in both cases registered in writing before verification. Or the recipient may make a rough sketch of a simple object that the agent was handling, drawing, or even thinking about—say a ring or a cross, a key or a banana. Just as it is now possible to send across the Atlantic, by some television method, a facsimile of a cheque, so, but probably in some very different way, the agent with a horseshoe in his hand can so influence the recipient that he on his part draws a horseshoe!

For the sake of clearer argument let us keep, to begin with, to the relatively simpler phenomena of telepathy or thought transference, where a living agent influences the recipient from a distance, so that the latter is able to tell what the agent was thinking about. Let us keep to what is called "intentional telepathy," where the agent seeks to influence and the recipient is willing to be affected. Let us also avoid for the present the more complicated cases where two or three people widely separated in space combine in expressing by automatic writing a somewhat subtle single thought. Let us also,

for the present, avoid discussing the possibility that the agent may be a person no longer existing as a protoplasmic organism. As a matter of scientific procedure, it is probably best to begin with clear-cut cases of simple thought transference or telepathy between a living agent and an attuned recipient or percipient.

We have introduced the word "attuned," since only some people are successfully recipient; and it must be added that some agents are much more effective than others. It should also be noted that for a large number of cases, though not for all, there is not a shadow of doubt as to the bona-fideness of the recorded experiences; and the number of such reliable cases is, for certain phenomena, large enough to rule out merely "chance correspondence." The evidence for telepathy is given at length in the Proceedings of the Society for Psychical Research, and an enquirer who wishes to investigate the subject seriously should consult the data in these volumes. The impression conveyed to an expert of the calibre of Professor William McDougall is that "the evidence for the reality of telepathy is of such a nature as to compel the assent of any competent person who studies it impartially." In scientific discussion one does not care to appeal to big names, but, as in agreement with McDougall, we may cite Sidgwick, James, Forel, Freud, Bergson, and Driesch. Freud writes: "there is a strong case for accepting telepathy."

It appears to us that telepathic experiments have yielded reliable data well deserving the most thoughtful scrutiny. There is strong—if not conclusive—evidence that an agent can deliberately affect from a distance an attuned recipient, so that the latter is often able to tell what the former was concentratedly thinking about. In discussing the factuality of telepathy, Professor Hans Driesch, who used to be a very skilful experimental

embryologist, playing the most beautiful tricks with eggs before philosophy claimed his whole service, has some caustic remarks on those who have decided beforehand that so-called "psychical" phenomena "never can and never will be."

The philosopher remarks, in his *Crisis in Psychology* (1925), "Such people, who were with God when He created the world, and who know what He was able to do and what not, never die out." It seems nearer to scientific temper to keep an open mind, and to be willing to consider detachedly the "factuality" of the data which careful students of telepathy have presented. It seems to us that there are many well-documented cases which strongly suggest that a living agent can specifically influence a susceptible percipient at a distance.

But it will be noted that our admission is far from saying that an agent can specifically affect an unwilling percipient, or that the percipient can be informed by a deceased agent, whatever that may mean. Nor does an admission that there are facts to be accounted for involve the acceptance of any of the particular theories of how telepathy comes about.

Many of the records of cases seem to the scientific sceptic to be sadly lacking in precision. They do not show sufficient incredulity. Let us illustrate. (1) When *P* in England makes an outline of a dumb-bell which *A* in France is holding in his hand, the experiment should be increased in value if *A* also drew the dumb-bell and put the sketch in a sealed envelope to be opened by the experimenter when *P*'s corresponding sealed envelope is opened—all in the presence of accredited witnesses. (2) Common sense suggests that we, the interested outsiders, should be told the percentage of failures and successes and negative results. It would also be of value to analyse the failures, to discover, for instance,

whether the percipient could sketch a well-defined object of an unfamiliar kind or shape. Some of the percipient's drawings—e.g. of the agent's fish—remind one irresistibly of Shakespeare's "very like a whale."

(3) In cases where the percipient is affected in a definite informative way, it seems a little elementary that we should not always be told the precise relation in time between the agent's effort and the percipient's experience. How often have the clock-times been adjusted so as to prove simultaneity or show the exact time-relation? It would be quaint if the percipient's experience sometimes came first! (4) It is very striking that a percipient member of Professor Gilbert Murray's family circle should be able to outline a scene that another, the agent, was silently thinking about—the scene being sometimes from a book that the percipient had not read; but it seems to us that there is, in less careful hands, a tendency to lug in, as evidences of telepathy, various types of experience that can be accounted for with fewer assumptions.

Just as there are uniformities in bodily processes, so there are in mental sequences. It would not be necessary to invoke telepathy to explain that tens of thousands of Englishmen widely distributed in space are thinking more or less simultaneously in the morning of bacon and eggs. Two good companions, such as husband and wife, often break a silence synchronously with the same remark. Simultaneity of thought may readily occur between intimately acquainted percipient and agent, who agree to think quietly about the same time (so as to secure similarity of external suggestion), yet the hypothesis of a "message" is unnecessary. Far too little has been made of this uniformity of mental processes, well known in the extreme case of identical twins, who may at the same time buy the same present for one another—one in Edinburgh the other in London.

Finally, it seems good sense that we should seek to become better acquainted with simple intentional telepathy before dragging in the complexities of so-called "spontaneous" and "multiple" forms, or the alleged telepathic communications from the departed.

Suppose it be certain that *P* in England can be specifically and informatively affected by *A* in France, how is it done? There is no hurry about this question, for our first scientific duty is to collect more facts and with increased precision. But *suppose we accept* the "factuality," accepted by thinkers like Bergson and Driesch, Freud and McDougall, we cannot help thinking of the possible *modus operandi*. (1) Some say that a "purely physical" influence passes from *A* to *P*. But apart from electric fishes and luminescent organisms no living creature is known to give off radiations. (2) Some say that the phenomenon is "purely psychical," and we are told that the impression passes from the agent's consciousness to his subliminal mind, thence to the corresponding level in the percipient, whence it emerges into his conscious mind. But science has not really got so far as all this would suggest. (3) Some cautious enquirers object to such terms as "purely physical" and "purely psychical," pointing out that all we are sure about is that two highly strung nervous organisms are in the mutual relation of agent and percipient, but beyond the range of known sensory influence. (4) There are some, not parsimonious with hypotheses, who believe that *P* is not directly influenced by *A*, but through the intermediation of a super-mind in which all mind is, so to speak, pooled. We are personally unable to breathe at these heights of speculation. (5) If we agree with the authorities cited, that there is actual thought transference from a distance, then the unsolved problem is as to the means by which this is brought about; and we have given a respectful

statement of the suggestions that have been offered. But in the cautious scientific mind there arises a prior problem: Is telepathy, *telepathy*? There is no doubt that there are phenomena to be explained, but are they such that they necessarily involve any travelling influence or thought transference at all? Thus, we have sympathy with those who would suspend judgment until more account has been taken of the uniformity of mental processes and sequences in kindred minds, for this might explain many results that are assumed to be telepathic. It seems to us *possible* that the term "telepathy" is a misnomer, and that the real scientific riddle may turn out to be: Is telepathy, *telepathy*; and if not, what?

WHAT LIES BEHIND CLAIRVOYANCE?

Telepathic phenomena, or the apparent conveyance of information from a distance beyond known sensory range, must be given a rank higher than the more familiar clairvoyance, for the experimental evidence is more precise and critical. Yet many scientific investigators have admitted that there is a fair case for accepting clairvoyance; and it is certainly one of the scientific riddles. The pitch has been somewhat queered by clever exhibitors, from the drawing-room to the stage, who use a code of communication so subtle that it escapes detection; but beyond that there is a big residuum to be explained.

The best experiments in clairvoyance are those in which the percipient declares the nature of some card, drawing, or object enclosed in a sealed envelope and unknown to anyone present until the envelope is opened. If someone else in the room is aware of what was put into the envelope, there is a possibility of literal telepathy, if that is a possibility, not to speak of collusion. A good form of the experiment is that in which the envelope to be "seen through" is fortuitously selected from a number of somewhat similar envelopes, containing, for instance, different cards from a pack, or different letters of the alphabet. When the clairvoyant is successful many times in naming the card or letter there is a remarkable phenomenon to be accounted for; and one of the clues is probably to be found in the observation of growing fatigue and increasing error on the clairvoyant's part. There is a distinct "fatigue curve"; the clairvoyant starts well, has a run of successes, and then begins to get tired

or bored, and, as failures increase, in non-scientific circumstances, worried or confused. This fatigue is said to occur in faked clairvoyance, where the percipient becomes tired or confused in reading the code; but it has been observed in carefully conducted scientific experiments. The clue it affords is the suggestion that sensory powers are being exercised beyond their usual limit.

Before assuming, as some too readily assume, that the phenomena of clairvoyance are purely "psychical," whatever that may mean, it is necessary to do *more* toward exhausting the possibilities of abnormal sensitiveness or hyper-æsthesia; and it is also necessary to have *more* blindfolding experiments to show whether vision plays any part in the clairvoyant's discoveries. For scientific purposes it is essential to have numerous experiments, and a record of the percentage of successes and failures, and a note as to the blindfold or open-eyed state of the clairvoyant. What would an ordinary bird say to a dog tracking its master's footsteps by an olfactory sense, which is superlatively developed in dogs, but almost in abeyance in birds? Ants and bees utilize olfactory cues which mean nothing to ordinary men, though we have seen a hypersensitive student make straight for a particularly disagreeable fungus in the heart of a thick wood.

Many people have no difficulty in hearing the high-pitched voices of bats, to which most of us are deaf. A horse in a stable may recognize its master's footstep as he approaches over the cobble-stones, and a house-dog knows the car's individual noise from a distance. We were told by a physician that a patient seriously ill complained bitterly of the frequent bell-ringing between two and four in the afternoon, whereas, of course, there was no bell-ringing at all, not even next door. As the

patient persisted, the physician had the disturbances counted for a troubled hour, and found, as he had suspected, that the number corresponded with that of the bell-rings in a consultant's house several (we forget how many) doors away.

Also to be taken account of are phenomena of hyper-æsthesia in hypnotized subjects, who sometimes show an extraordinary sensory acuteness, both visual and auditory; and one does not need to go beyond the range of normal field naturalists to find irrefutable evidence of an acuity of sight that seems to ordinary observers almost miraculous. Often have we seen a botanist in a slow-going pony-cart pick out with his keen eye an unusual flower amid a tangled bank of vegetation; and even more remarkable, perhaps, is the expertness of ornithologists and entomologists in identifying a passing bird or insect—a feat that often admits of subsequent verification. What we are driving at is the common-sense conclusion that the limits of sensitiveness vary greatly and are not to be dogmatically defined. The tactility of the blind will occur to all, and many people, before they rise in the morning, know in their bones that the wind is in the east—sometimes, it must be admitted, when it isn't.

In emphasizing hyper-æsthesia, we seek to indicate the intellectual danger of being too sure about the limits of our senses. But to extend the limits to include what is not experimentally guaranteed, or at any rate hinted at, is credulity for the time being. We are susceptible to ultra-violet rays, but there is no evidence that we can use them in our ordinary vision, as ants and bees do. Some people have extraordinary acuity of vision, but sceptically conducted clairvoyant experiments have not demonstrated that our eyes can tell us the nature of the trinket that lies within a thick-walled closed casket. That is much more incredible, on the hyper-æsthetic hypothesis,

than telling the nature of a card held face downward or enclosed in an envelope. If scrutinized records of closed-casket experiments were forthcoming in numbers sufficient to eliminate chance successes, it would be necessary to abandon the hyper-æsthetic interpretation of clairvoyance. In our judgment it is too soon to do so.

To what has just been said as to the difficulty of seeing into a thick-walled box, it may be objected that radiography has enabled the surgeon to see where the bullet is deeply buried in the bone, and the physician to detect the tuberculosed patches in the lungs, and the merchant to tell whether there is any pearl in the unopened oyster. And is it not possible for people in America to see a cheque which is exposed to view in London? Is there not a physical contrivance so delicate that it registers the fact that someone opened the door of the dark room in which it stands, and held his hand outstretched for a minute?

But these devices do not help us much towards an understanding of clairvoyance. The rays used in radiography pass through the bone, but are interrupted by the bullet; hence a smudge on the plate. It is easy to get a view of the whole skeleton of an undissected frog; but there are no special rays going to or coming from the playing-card in the sealed envelope!

Most ants have very acute vision, and are able to see the ultra-violet rays to which we are blind. Some are supposed to have such fine sight that they are guided by a star, or at any rate by starlight, on their nocturnal rambles in very thick darkness! But some ants are blind, and one of these, called *Anomma*, which means "without eyes," is of peculiar interest. The *Anommas* are very aggressive ants, sometimes devouring chickens in the hen-house; they often march in broad daylight and behave as if they saw things; the blind troupe has been seen to react to a shadow of a cloud. It has been shown that

they have very highly developed senses of smell and touch, and there is evidence of a "photo-dermatic sense"—that is to say, a sensitiveness to light and shade through nerve-endings in the chitinous covering of the body. Of this skin-sense there is ample proof in a number of lower animals, and its existence should give us pause in regard to the limits of our own susceptibilities.

In this connection some reference should be made to the strange conclusions (1920: trans. 1924) of Jules Romain, who found that some people, especially in a state of mild hypnosis, could see by means of their skin, utilizing minute integumentary structures which are sometimes called Ranvier's menisci. Not only could the blind or blindfolded subjects distinguish light and shade, but they could read a page of a book! Personally we fancy that there was some snag in the experiments, but some of the conclusions were vouched for by Anatole France and Romain's book excited some highly coloured controversy. It seems to us to prove too much that a blindfolded man could read a column of an ordinary newspaper by holding it to his bared bosom, yet what are we to make of the photo-dermatic sense of some insects with their apparently callous cuticle? The moral is, not to be too sure that we have reached the limit of what our senses can do for us; and this expresses our attitude to the phenomena of clairvoyance.

Professor Hans Driesch, well known as an abstruse philosopher, and in other circles as a highly skilled experimental embryologist, has avowed his thorough belief in clairvoyance. In his *Crisis in Psychology* (1925) he says: "By clairvoyance we understand the abnormal acquisition of knowledge about facts other than another subject's knowledge, i.e. about material states or conditions. Clairvoyance may relate to the past, to the present, and probably also to the future." Later on in the book he

tells us that, after long hesitation, he has become convinced of the possibility of clairvoyant *prophecy*.

Prophecy is obviously a far cry from the innocent little powers that we have spoken of in this chapter, and this leads us to emphasize our method of treatment, as previously suggested in the case of telepathy. The procedure that seems to us most in the line of science and good sense is to begin with the simpler phenomena, making surer of them before even discussing such high flights as prophecy. Let us begin with reading through an envelope or a door; let us obtain data from open-eyed performances before blindfold ones; let us deal with wide-awake clairvoyants before utilizing those in a trance; let us enquire how far the phenomena can be linked to hyper-æsthesia in man and to extreme sensitiveness in some animals. There is much to be said for keeping clairvoyance in the strict sense entirely apart from so-called "second sight," crystal-gazing, divination, or seeing of visions—where we have in many cases to deal with the expressions of an exalted state of mind.

So far our suggestion has been that the facts of elementary clairvoyance may be brought into line with the facts of hyper-æsthesia. It is possible that the sure and certain elementary phenomena require no special hypotheses of unknown "rays" or mysterious "psychic" powers, meaning by "psychic" here something beyond the physiology of the senses.

But the clairvoyants claim to be able to do much more than can be interpreted by any hypothesis of hyper-æsthesia that we are at present justified in bringing forward; and the question is whether these higher feats of clairvoyance are sure and certain like those which we have called elementary. Let us illustrate.

An investigator in a house several doors away selects three English classics and opens them on the table at a

well-known page, and no one but he knows either book or passage. Yet this is declared by the clairvoyant to his or her circle in the distant house, and the gist of the passage is given, even when the passage, as such, is unknown. Then the clairvoyance is verified. If telepathy is possible, this might be telepathy.

Another of the higher feats of clairvoyance, often exhibited in conditions where there is more credulity than criticism, is telling some story about an unfamiliar object which is put into the clairvoyant's hand. It is possible, however, that the clairvoyant's gift in this case is nearer what is called divination, to which we shall refer later on in connection with crystal-gazing. All that we can say at present about these higher feats of clairvoyance is that if they are absolutely reliable they put the hyper-æsthesia theory out of court and remain an unsolved problem.

The power of discovering underground water without digging or boring was known in ancient days, and it is successful enough to-day to afford a means of livelihood for professional dowzers. Independent of common sense and of geological judgment, though sometimes doubtless with help from these, the dowzers find water; and it may be that the rod with which Moses struck the rock and liberated water was a "divining rod," such as dowzers often use. It is not essential, but the water-diviner often holds a forked stick in his hands, and its twisting movements indicate when there is water hidden in the ground underneath. These movements are due to muscular twitchings, and these are probably produced automatically in response to subconscious excitements, evoked by the presence of water, or by something, e.g. electrical stimulation, associated with the water. Some dowzers are quacks, but others seem to be hyper-æsthetes; and there is no warrant for invoking mysterious psychical

powers until the phenomena of hyper-æsthesia have been more adequately explored. The unsolved problem is the nature and the location of the hypersensitiveness of the dowser—a hypersensitiveness which should be ranked, we think, along with clairvoyance, though sight is not specially concerned. It is not necessarily restricted to the detection of water, for a few people can find metals—though rarely gold.

CHAPTER XLIV

HOW EXPLAIN CRYSTAL-GAZING?

It is natural to think that there must be something in a practice so venerable as crystal-gazing or "scrying." Could it have lasted so long if the gazers or descriers had not been rewarded? In the crystal, the mirror, the precious stone, or the pool of water, the scrutinizer became aware of images and occurrences, which he held to be disclosures of the otherwise unknown—in past, present, or future. That the professional gazer often saw nothing, often invented what he said he saw, and often invested his disclosure with a mystery in which he did not in the least believe, are familiar and doubtless justified reproaches. But they do not affect the certainty that several scientific investigators and hundreds of simple-minded enquirers have seen visions, or have had the hallucination of seeing visions, by gazing into crystals or the like. The problem is to explain the phenomena.

Scrying seems to have been practised all over the world, but by many other methods besides gazing into crystals. The diversity shows that the visualizing condition may be induced in the observer by staring into many different kinds of things, but the rarity of some methods, such as gazing at the glistening liver of a disembowelled animal, and the obsolescence of others, such as poring over the viscera, may serve to show that some objects, like crystals and precious stones, proved not only more convenient, but much more effective than others. Among the well-known objects used in scrying, we may mention, besides crystals, a mirror, a sphere of glass or natural crystal, a disc of polished metal, a black stone, a ring, a bowl of water, a pot of ink, a cup of wine, a spring.

The less familiar include a sword-blade, a polished fingernail, a silver lamp, the lock of a door, a golden ball. Evidently almost anything will serve that has a reflecting surface; the *sine qua non* is staring. We have sometimes wondered whether the knowing way in which our host holds up and gazes at his glass of sherry is not in part an unconscious survival of scrying.

Andrew Lang defined the faculty of scrying as that of "seeing faces, places, persons in motion, sometimes recognizable, in a glass ball, or in water, ink, or any clear deep." The crystal-gazer seems to see pictures, and if he is a good seer he sees them not in his "mind's eye" but as it were objectively in the depths of the crystal or bowl of water, or, so to speak, on the other side of the looking-glass. The only really puzzling part of the phenomenon is the apparent objectivity and the way in which one event often follows another, *as in a dream*. But let us ask the crystal-gazers what happens to them.

Trustworthy and reasonable students of scrying, such as Theodore Besterman, whose *Crystal-Gazing* (Rider, 1924) can be strongly recommended, are agreed that the conditions of success vary greatly with the individual. Some people see nothing anywhere; others can see "heaven in the palm of the hand," Blake's well-known expression probably referring in a poetic glancing way to the use of a handful of water as a medium in divination.

It seems that the clearest visions are seen when the light in the room is not brilliant, and when there is not much reflection from the crystal itself. Quietness is an aid to vision, and Andrew Lang's experience was that it is best to be alone. The gazer should be in good form, and willing to gaze patiently, but without any strain, for five or ten minutes. The mental attitude should be like that of a microscopist looking through his lenses at a sample of water from pond or pool, waiting to see what

will become active or enter the field of vision. He waits and sees, that is all; and so, we believe, it is with the scryer. Andrew Lang scouted the idea of there being anything abnormal: "One has a notion that the born scryer is a pallid anæmic girl, with large, mysterious eyes, hollow cheeks, untidy hair, and a strong aversion to exercise in the open. But the scryers whom I know are healthy, jolly people . . . often vigorous athletes, sportsmen and sportswomen, golfers, tennis players, bicyclists, and salmon-fishers." There is no doubt that he took a robust view of crystal-gazing!

Some people are so unaccustomed to concentration of any kind that they become rapidly fatigued when it is required of them; and crystal-gazing is not for inattentive minds of this type. But, as contrasted with hypnotic experiments, there is nothing fatiguing or dangerous in crystal-gazing, though, perhaps, on the other hand, there is nothing particularly bracing or beneficial. Probably the best scientific experiments are those of Miss Goodrich-Freer, who writes: "I wish to say, as emphatically as possible, that in my own case these experiments are neither the cause nor the effect of any morbid condition. . . . The four years during which I have carried on experiments in crystal-gazing have been among the healthiest of my life."

Most of the successful crystal-gazers record a preliminary experience before they begin to descry shapes and faces. There is a clouding or befogging within the crystal or the fluid, probably corresponding to some physiological optical change; and from amidst the clouds or mist there emerge pictures. In some cases, however, there is a preliminary lighting up of the interior of the medium used. What is seen may be a single image of a person or a scene, but in the finer experiences there is a succession of pictures either continuously, as on a film, or in a more

staccato fashion, as in a magic-lantern show. There may be a natural sequence or apparent disconnectedness.

(1) Our first proposition is that only certain people can divine. One recalls Joseph's remark to his distraught brothers when the silver cup had been found in Benjamin's sack: "Did you not know that a man like me would be sure to use divination?" And previously his house-steward had said to the brothers: "Is not this the cup from which my lord drinks, which in fact he uses for divination?" Even in those days it was recognized that it is not given to everyone to be a scryer!

(2) Our second proposition, to which many will demur, is that crystal-gazing is not intrinsically hypnotic. Some people pass rapidly into the hypnotic state when they stare at some bright object, and crystal-gazing may induce hynosis. But this is, in our judgment, almost incidental. The records suggest that the clearest visions are seen by gazers who are absorbed, but certainly not hypnotized in the ordinary sense of the term. No hard and fast lines can be drawn, especially when use is made of such cautious phrases as "incipient self-hypnosis"; but there is no doubt that the crystal-gazer may remain as normal as a preoccupied microscopist.

Morton Prince, a shrewd psychologist, said that the gazer appeared to him "like one who, at the theatre, was completely absorbed by the play, and in that sense was unconscious of the surroundings, but not at all in a trance state." Mr. Besterman, who writes very judiciously, says: "I have myself never observed, in watching a scryer during his visions, anything more than the ordinary abstractedness of a person watching something with care so as not to overlook any detail." Thus, while the recorded data convince us that the gazing *may* induce a hypnotic state, and that visions may be seen in that state, there are more abundant and equally convincing data which show

that crystal-gazing may succeed with those who are not in any definable sense hypnotized, or even known to be hypnotizable. That they become absorbed, dreamy, pre-occupied, must be admitted, but we doubt if anything is gained by calling this "hypnoid." Many people enjoying a fine view are equally deserving of the adjective.

(3) No one doubts the power of suggestion over the senses, especially of good-natured non-sceptical people. If the suggestion is emphatic enough and is conveyed by some impressive personality, the plastic mind sees what it is told to see. A continental zoologist, whom we knew well, used to tell his junior students individually to look at some distinctive specimen under the microscope, and get them to observe it when it was not there—the subsequent disclosure of the cruel deception being intended as a lesson in scientific scepticism. We doubt very much the psychological soundness of the trick, and the complaisantly obliging student's discomfiture remains painfully in our memory after forty years; but it illustrates what is undoubtedly a factor in many of the cruder forms of crystal-gazing. "Look into the crystal and you will see a dog," and of course you do. "Look into the bowl of ink and you will see the thief who stole your watch"; and if you are so disposed you may see a fugitive face.

So in our youth did the servant-girls at Hallow-c'en glimpse their future husband looking over their shoulder as they gazed, with due precautions, into the mirror. But there are many scryers who see pictures apart from any suggestions, unless one supposes that these are always floating about like microbes in the air. Many believe that the picture which the gazer describes is the outcome of definite telepathically conveyed information, but there is more than one large hypothesis in this theory, and it is too like explaining *obscurum per obscurius*. In pursuance of our method, we rule out suggestion, whether direct or

telepathic; and we rule it out not in any dogmatic fashion (see previous chapters), but because there are hundreds of instances of successful scrying to which the theory of suggestion cannot possibly be applied. We grant that suggestion is sometimes a factor, but it cannot be regarded as in any way indispensable.

(4) As organisms we are very unequally endowed; thus some are born with very acute vision and others with very sensitive hearing. Young people in particular are often able to make almost photographically precise pictures of what they see, especially when it strikes the chord of interest. The capacity may be allowed to atrophy for lack of exercise, but it can be developed into a talent. Much can be gained by discipline in visualizing—staring at a scene, closing the eyes and seeing with the eyes shut, opening them and staring again—it is good fun in early years—that is the way to fill the picture gallery of the mind. All eye-minded people have something of the gift, but some have it extraordinarily, and have cultivated it still more.

Such are the successful scryers, and not even a crystal is needed. Just as Wordsworth saw the dancing daffodils whenever he pleased, so the visualizers have only to close their eyes to see visions. Sometimes these are old friends, pictures that we often look at; sometimes, however, they are strangers, and these are emergences from our subconscious, photographs we took without knowing, because we had formed the habit which Davies calls, “standing and staring.” Wordsworth said that he revived the picture of the daffodils when he was in “vacant or in pensive mood”; and what the crystal or other medium does is to produce a state of restfulness and receptivity, when the stage is clear and our previous mental pictures have a chance to assert themselves. We do not will to scry; we let the mind show off its treasures. In many ways the

revived pictures are like those seen in sleep, but, so far as we know, there is nothing of the bizarre phantasmagoria that is characteristic of many dream-pageants.

In old days it was regarded as important to get an innocent boy or girl to look into the crystal or the beryl stone; and while the successful results might mean that the young are more susceptible to suggestion, seeing what they are told to see, or that they let themselves go more readily and describe more sincerely what they observe in the medium, the success might be due to the fact that the harvest of the eye is richer in early years.

The word "hallucination" is often used by psychologists in reference to the pictures seen in crystal-gazing, but it does not seem to us to be very happy. The only "hallucination" is in the apparent *objectivity* of the pictures, which seem to many scryers to lie in the recesses of the medium used. But this is an optical illusion, and its incidental nature seems to us to be indicated by the fact that many people can see the same kind of picture by simply closing their eyes in appropriate surroundings. Myers estimates the percentage of successful crystal-gazers at about one in twenty, but that is probably far too generous. As Ruskin frankly told his generation, the number of people who can really and truly see is lamentably small.

There are some old records of crystal-gazing—with good names to them, too—that we cannot in the least explain in scientific terms, but we know how difficult it is to get accurate records of what happened no farther back than yesterday! For the great majority of cases we think our theory holds, that crystal-gazers are people with very keen visualizing power, and that the pictures they see are revivals of previous experiences, sometimes kept in mind, sometimes surging up from the subconscious. That there can be divination of the past or the future by any form of scrying we do not for a moment believe.

WHY DO WE DREAM?

The probability is that people dream much more nowadays than their ancestors did in olden times. Flowing into our minds every day there is a much stronger stream of exciting news, especially sights, sounds, emotional suggestions, and startling information. We live our lives at a quicker pace; we indulge in more constant stimulation of many kinds; we are ceasing to be content with quietly thinking; we are less accustomed to having our bodies tired out with honest work; we have less natural sleep, and we dream much more.

What a to-do our ancestors made about dreams such as many people have scores of in a year. What a vogue the interpreters had, and what short work Freud would have made of their interpretations, as post-Freudians of some of his! In our boyhood an old pedlar-woman used to bring to the kitchen door in her emporium of a basket little booklets that "told dreams" and were eagerly bought. Perhaps she has her counterpart still, but our impression, based on many talks, is that dreams are now so much commoner that they have become commonplace. It is no longer "quite the thing" to talk about your dream at the breakfast-table, partly because everyone else can tell a better one, and partly because we have come to know, especially through Freud, that dreams are more awkwardly self-revealing than our grandparents imagined.

Our inner or mental life may be compared to a stream, whose upper layers are illumined by the light of consciousness, while the deeper layers are dark and known to psychologists as the subconscious, or, at a greater depth, the unconscious. As everyone knows, eddies on

the surface of the stream sometimes have a strong influence on the depths, and conversely there are uprisings from the subconscious or the unconscious which assert themselves at the conscious level, both in waking and in sleeping life. The dreams we know about are mostly uprisings from the lower levels of our mental stream, which find a chance to assert themselves in consciousness when there is a relaxation of control, or when the surface is not crowded with sense-impressions. Our life, both mental and bodily, is normally continuous, and dreams are self-expressions when the higher faculties of reasoning and control are more or less at rest, and when the closing of the sensory doors and windows has brought quietness. The uprisings from the depths of the stream may be so powerful that they partly arouse the higher activities, without awakening the sleeper; and these are the dreams that we most remember.

There is no unsolved problem in dreaming by itself so long as we do not raise the question of the nature of consciousness. Dreams are expressions of our mental life when we are on the low gear of sleep. Even among animals there is evidence of dreaming, as in dogs and cats, horses and monkeys. Man has no monopoly of dreams; he is not a Melchisedec "without descent."

The mists that have formed round dreams are partly due to making too sharp a contrast between our sleep-life and our ordinary daily life. In the law-court the prosecutor asks the witness: "Was he asleep or awake when you saw him?" But we must agree with Hegel and common sense that between black and white there are two shades of grey, and between deep sleep and wide-awakeness there are inter-grades familiar to the "light-sleeper" and the drowsy traveller. Similarly we cannot draw a hard and fast line between the night-dream and the day-dream, both of which have various

grades. In night-dreams part of the mind insists on remaining awake, while much of the mind and the bulk of the body are asleep. Here we are ignoring the unsolved problem of the relation between Mind and Body, which looms as large for our waking as for our sleeping.

The science of dreams has made relatively little headway, mainly because of the largely unverifiable nature of the data, but partly because those who have found some clue have insisted that theirs is the one and only interpretation. Thus there is sound sense in the Freudian theory that a dream is an imaginary fulfilment of a long-suppressed or long-repressed wish; but there are many dreams to which this interpretation does not apply. Let us indicate, then, some of the different kinds of dreams, always with the saving clause that they shade into one another. It will be noted that our classification of dreams is according to their nature, not according to the causes that provoke them. We shall refer to these later on.

The most primitive dreams are probably reawakenings of very early experiences, such as those of babyhood, perhaps even of antenatal life. A very careful observer has told us of a young puppy, still with its eyes shut and still unable to co-ordinate its limbs in locomotion, which in its sleep went through hunting movements with its paws, uttered premature barks, and showed facial expressions as if it were on the hunt. But it had never even crept about, and it was sleeping cradled in a girl's arms. Many a sleeping dog has hunting-dreams, but these are doubtless reminiscences of its own experiences; in the case of the very young puppy there was perhaps a reawakening of racial predispositions, forming part of the Primary Unconscious.

A not uncommon human dream has to do with floating through the air, usually not very far off the ground. The head is thrown back, as in floating in the sea, and

the lower parts of the legs are retracted. It is not usually a vague flotation, but occurs over a familiar mile of road, or down a well-known slope. When it is often repeated, as with some dreamers, it acquires trimmings, such as the presence of admiring spectators, and it may become, as is often the case with dreams, associated symbolically with a particular mood, such as ambitious endeavour. But in its simplicity it is just the pleasant experience of being able to float in the air. Sometimes it awakens higher levels of the mind, to the extent that the floating is not successful unless it is down a slope or in association with air-currents. It may occur in people who have no experience of floating in the sea. Various theories have been suggested to explain this form of dream, e.g. that it is related to the baby's early experiences in the bath. One psychologist of distinction has sought to relate it to the piscine chapter in the pedigree of Vertebrates—some hundreds of millions of years ago! We would hazard the suggestion that it is an organic reminiscence of floating in the amniotic fluid before birth. All these theories have to face the obvious difficulty that the dream-experience is of floating in air, not in water. In any case, flotation may serve to illustrate a primitive type of dream, which we may call "primary reminiscence."

After a short visit to Paris, crowded with naïve enjoyment of painting, sculpture, music, and witty conversation, a Scots student went to study marine zoology at a quiet laboratory on the coast of Normandy. There he enjoyed, night after night, without any suggestion of abnormal excitement, a succession of brilliant reminiscent dreams, phantasmagorias of the Louvre, processions of statues (it was before the era of films!) and kaleidoscopes of theatres and of Paris itself—all joyous and wholesome, but extraordinarily vivid. This is typical of the reminiscent or echoing dream, in which the dreamer, usually after

unwonted experiences, lives his life over again. It must be confessed that these sleep-reminiscences are not always noble; that depends largely, though not wholly, on the waking morale.

A third type of dream, developed from the second and presenting no special problem, consists of combined reminiscences. Everyone knows how unpredictably in desultory conversation our mind or attention flits from one subject to another, and we have to explain to our friend what the connection was that led us to speak of vanity-bags, when he spoke of freshwater mussels; and this whimsicality of association is still more marked in dreamland, where nothing ever seems absurd. Many dreams are jumbled recombinations of memory-pictures and experience-reminiscences; and they are not more difficult to explain than the frequent irrelevancies of reverie. The controlling part of the mind is not awakened; and there is never any of that introspection which detects absurdity.

A medical practitioner, lost too early to his art, once told us that for several years after his Final Examinations, over which he was unnecessarily anxious, he had nightmare dreams of his *viva voce* ordeals. This is a common type of dream, where some exacting experience reverberates. When a man is becoming wearied in service, in the pulpit, in the operating theatre, in the lecture-room, he often becomes over-anxious, over-afraid of not doing his work as well as usual. This sort of dream becomes commoner when a man is beginning, in his waking hours, to think so much about his everyday work that it is ceasing to be a pleasure. The associated anxiety-dream may be a danger-signal, indicating that it is time to quit, if one can; yet it may occur, probably in hypersensitive natures, when there is no objective reason for any loss of confidence. Yet whenever some obvious waning of power

sets in, as in actor or surgeon, the anxiety-dream may become a phobia. In mild forms it is a very common type of dream, and robust natures may utilize it, like a pain, as a warning. Its reference is sometimes to a humiliating failure in the past, or to an ordeal that has to be faced in the future; but it is a mistake to suppose that it has any necessary connection with an inferiority-complex.

Just as no one would at present discuss astronomy without first studying under Eddington and Jeans, so no one should discuss dreams without first appreciating the contributions that have been made by Freud as initiator, and by investigators like Adler and Jung as continuators and critics. Even if one is convinced that Freud over-emphasized the scope of the sex-urge in ordinary human life, we must admit that he introduced psychological precision into the study of dreams, that he analysed and illustrated a particular type of dream—the expression of repressed and unfulfilled desires—and that he showed, as he says, that “the interpretation of dreams is a royal road to a knowledge of the part that the Unconscious plays in the mental life.”

Few dreamers are unfamiliar with the type of dream which Freud particularly studied—the expression of unfulfilled desires. When the sleeper is in dreamland, where everything is possible, when the stage is relatively empty, when the preoccupations of wide-awake life are having a rest, when the higher controls of the mind are in abeyance, then there emerge the often very vigorous ghosts of what we would have liked to have done or been or enjoyed. Sometimes they hustle upwards from the secondary or Freudian Unconscious of repressions or complexes, but sometimes they come from nearer the surface and give free course to the ambitions that we only dare to whisper to ourselves; sometimes they have to do with sex, at other times with longings after intellectual or

æsthetic excellence, which usually lie unspoken in the abysses of our waking mind. Sometimes the wish-dream may be a good dinner, sometimes getting the better of a rival who offended our dignity many years before.

Sometimes this type of dream becomes very habitual, and in many such cases the object of desire hides under the cloak of a symbol—the interpretation of which affords good exercise for the ingenuity of the psycho-analyst.

The most delightful kind of dream is the adventure-dream, in which the happy sleeper goes off on his own, without any handicaps of ways and means, space and time. Perhaps he goes on a voyage, or explores a glen, or finds a new kind of animal, or makes a big success of an undertaking, or invents something novel, or gets a new dress and has a party with delightful guests, or simply wanders on with great content in the land of heart's desire. The only difficulty about these adventure-dreams is that they sometimes involve scenery and *dramatis personæ* quite beyond the actual experience of the dreamer. It is probable that books and conversations and pictures supply the material in such cases, but it is a little puzzling that a man who never saw a surgical operation in his life should yet dream of one in very circumstantial detail.

The rarest kind of dream, admittedly difficult to understand, is that in which the dreamer arrives at the solution of some problem, sometimes mathematical, sometimes logical, sometimes practical. The sleeper seems to himself to reason well, to lecture well, to clear up a knotty point, and in some cases there is a registerable residuum in the morning. What is difficult to understand is that something is achieved that would in waking hours require the most resolute mental control; and it is this higher control that is conspicuous by its absence in typical dreaming.

It may be that this dream-cerebration, analogous to

unconscious cerebration in waking life, takes place very rapidly near the threshold of awakening; but the old view that dreams are usually very rapid and condensed has been somewhat shaken by modern experimental work. These *ratiocinative* dreams seem to us to be unsolved problems.

Having classified dreams as of seven types, let us turn for a little to the stimuli that provoke them. The advances of physiology and psychology make it abundantly clear that bodily and mental activities are very closely intertwined. The mind thrills the body to which it is thirled. The body often clogs the mind, which it nevertheless nourishes. A blot on the brain spoils a philosophy, and a touch of liver warps a kindly nature. On the other hand, a noble mind may master a frail body; and many weaklings have been makers and shakers of the world.

We do not know whether life is an unfathomed unity with bodily and mental aspects (BODY-mind at one time, MIND-body at another), or whether the mind is like a musician playing on the instrument of the body. That remains one of the major unsolved problems; but there is no doubt that the bodily and mental aspects are both real.

The significance of this as regards dreams is that many of them are of a somewhat commonplace type, being due to physiological disturbances that rouse the "mind" to activity when it ought to be asleep. Thus gastric and intestinal disturbances wake up a corner of the mind, and incite a particular mental activity which has come to be associated with this kind of disturbance. Certain types of dream follow lobster and others welsh-rarebit; and the less said about them the better.

The dream of floating through the air, to which we have referred, is frequently associated with dyspeptic disturbance; and other types are associated with irritation of the

colon, part of the large intestine. Why particular dreams should be associated with particular bodily disturbances we do not know, though we can sometimes guess.

In other types of dream, the trigger-pulling stimulus comes *from without*, not from within. It may be a noise, such as a shot outside the window; it may be the touch of an over-heated hot-water bottle; it may be a strong odour, such as burning wood. The scent of a resinous stick has been known to awaken the hunting-dream in a sleeping dog.

In man's case, the sensory stimulus from outside gets through the sleep barriers, but instead of awakening us, it merely starts a dream, which may or may not be relevant to the situation. By starting this sort of dream experimentally, it has sometimes been possible to time a dream; and it may be noted that while an apparently long dream may be all over in five minutes, there are indications that the pace is often much slower and the duration much longer.

But we cannot do more than illustrate the variety of stimuli that may awaken part of the mind when the whole should be sleeping. They vary from the extreme commonplaceness of transitory pain or pressure to the restlessness of an overworked brain-centre or the absorbing insistence of a serious worry.

The subject of dreams is still young, but it has been of service in revealing something of the subtlety of the Unconscious. Some people say that if we did more, we should dream less, and that neither we nor the world would be any the poorer. It may be, however, that dreaming is sometimes a salutary safety-valve, that it relieves suppressions and repressions, that it may give a useful warning to a wise interpreter, and that it may keep some of our ambitions from dying of desuetude. So at least we dream!

PART IV

IS EVOLUTION STILL GOING ON AND UP?

What is Evolution? In the wide sense it is a *process of Becoming*, in the course of which something new arises. There is no doubt that new stars are still appearing in the sky, and there are nebulae which seem to be making new solar systems far away in Space. If some stars die into darkness, other luminaries are being born. In the Universe as a whole there does not seem to be any evidence of either ending or beginning. There is within our intellectual horizon a ceaseless flux. Cosmic Evolution is going on.

At present within the chemist's reach there are ninety-two elements (less one gap still to be filled), and we know that a kind of chemical evolution goes on. Thus, uranium may give rise to ionium, which may give rise to radium. Or uranium may give rise to protactinium, which produces actinium, which produces lead. Or radium, by giving off helium, may produce lead. The meaning of this is that all the different elements are composed of units of electricity, positive "protons" in the centre of the atom, and negative "electrons" in zones outside. An average atom is like a sun and its planets. There is a solar core of protons and outside this there is orbit after orbit of electrons. Even as we write this, the picture of the atom is changing a little, but the large fact is secure that the ninety-one known elements, qualitatively so very diverse, differ from one another quantitatively, namely in the number and the position of their protons and electrons. But our point is that *chemical evolution is going on*, as we see in the succession or pedigree we have mentioned—uranium, protactinium,

actinium, lead. It is believed that "lead" is being born in about eight different ways; and since lead does not seem to be transformable into anything else, it may be argued that there is not here much evidence of "evolution." But we must get rid of the idea that "evolution" is synonymous with progress. Evolution is the becoming of something new, and it may be something new "down," as well as something new "up." To use terms less metaphorical than "up" and "down," we may say that evolution works in the direction of greater simplicity as well as in the direction of greater complexity. As has been often said, the tapeworm in its inglorious lot in man's intestine is an outcome of evolution as well as the lark at heaven's gate. We say "as well as," but not "as much as" for the simple reason that evolution in the world of life is *on the whole* "up," that is towards "differentiation" or complexity of parts, and towards "integration" or unifying of parts. Moreover, among higher animals there is an undeniable movement towards mental qualities, such as alertness, judgment, and aesthetic sensitiveness, and towards moral qualities, such as sympathy and synergy—qualities which man at his best has always regarded as best.

To return, for a moment, to *chemical evolution*, we find abundant evidence that it is still going on, though we must admit that so far as the earth is concerned the trend of chemical evolution (outside of the creative chemical laboratories) is all towards simplification, towards a running down of the clocks. The synthetic chemist is a veritable creator of new complexities, some of them life-destroying, like explosives, others life-saving, like thyroxin against cretinism; but in terrestrial Nature the transformations outside living creatures seem nowadays to be always from the more complex towards the more simple. It is probable, however, that in the colossal

laboratories of the sun and the stars, where atoms are torn to pieces and built up again, still unknown elements, more complex than uranium, may be in process of evolution. In any case it is safe to say that *chemical evolution is going on.*

EVOLUTION OF THE EARTH

All the cosmologists are agreed that the earth was once a fiercely hot nebulous mass which had its origin in a nebulous centre now represented by our sun. If evolution is a change, as Herbert Spencer said, from the homogeneous to the heterogeneous, then the earth has evolved, for it acquired a crust and a core, and zones between. It gained a hydrosphere and an atmosphere, and it certainly made progress in this sense, that it became fit to be a home of life. Probably the word to use is development or genesis, not evolution, but the fact is certain that the earth passed through a succession of changes, and became more and more interesting.

They say the solid earth whereon we tread
In tracks of fluent heat began,
And grew to seeming random forms,
The seeming prey of cyclic storms,
Till at the last arose the man.

This process of complexifying or differentiation was greatly assisted by the hand of life; thus green plants made a breathable air; in early Tertiary times grass began to cover the earth like a garment; the dainty Foraminiferal shells accumulated as future chalk cliffs; and coral polyps are still building beautiful islands. Sometimes carelessly, but often beneficently, man has carved at the earth, and still he casts mountains into the sea and turns the desert into a garden. It is of great value to see our present-day earth as only one out of many successive stages on which the drama of life has been played for untold millions

of years. Tennyson had a fine vision of the evolving earth :

There rolls the stream where grew the tree,
O Earth, what changes hast thou seen,
There where the long street roars hath been
The stillness of the central sea.

The hills are shadows and they flow
From form to form and nothing stands,
They melt like mist, the solid lands
Like clouds they shape themselves and go.

ORGANIC EVOLUTION

It makes for clearness to use the term "evolution" with a prefixed adjective, for there are several different kinds of evolution which have little in common save that they are all processes of Becoming, in the course of which something new emerges. Thus, as we have illustrated, there is cosmic evolution, chemical evolution, and terrestrial evolution. But our chief interest here is with none of these, nor with social evolution, but with the evolution of living creatures or organisms. How can we define this *organic evolution* which has led to the plant world and the animal world and ourselves? *Organic evolution is a natural process of racial changes in a definite direction, whereby new forms of life arise, take root, and flourish alongside of, or in place of, their ancestors, which were in most cases simpler in structure and behaviour.* In cases of degeneration and parasitism, the ancestors were not simpler, but the reverse. On the whole, however, organic evolution has been an advance. Life has been slowly creeping upwards. As age has succeeded age there has been an emergence of higher types with increasing freedom and mastery. The evolutionary process is not *necessarily* progressive, but on the whole it is an advance that is revealed by the history written in the fossil-bearing rocks. If a

fish does not show progress when compared with a worm, if a bird does not show progress when compared with a newt, then we must invent some other word to take the place of "progress," which admittedly had its first reference to human history.

IS ORGANIC EVOLUTION GOING ON?

Let us now face the question: Is organic evolution going on, or has it for the most part come to a standstill?

(1) Some organisms have certainly remained the same for ages. There are not a few conservative types which are known as ancient fossils and yet to-day, live on without appreciable change in millions of years. As examples may be mentioned: the Lamp-shell *Lingula*, since Cambrian ages; the Pearly Nautilus, since Cretaceous; the Mudfish *Ceratodus* since the Triassic. The New Zealand Lizard *Hatteria* with a pineal eye on the top of its head is a living animal of great antiquity, the sole survivor of an otherwise extinct class of Reptiles. There are many other animals which differ but little from their extinct fossil ancestors, and Darwin called them "living fossils." But there is no difficulty in the fact that evolution sometimes stands still, for if a creature has attained to an harmonious constitution and to a balanced adjustment to a more or less permanent condition of life there is no reason why it should change if its environment remains the same. If novelties crop up now and again they would be nipped in the bud. We may say, then, that in many living creatures evolution has stopped for the time being.

(2) On the other hand, when we settle down to study species carefully, weighing and measuring one character after another, we find that there is often great variability. Among our common birds and mammals, the members of a species seem to the ordinary eye practically identical,

but this is not the actual state of affairs. Many of them exhibit continual fluctuations, a little more of this and a little less of that, and these slight variations form part of the raw material of evolution. Every now and then there is something striking, like a white blackbird, but probably more important are the small variations that only the experts notice. Lotsy speaks of a collection of 200 specimens of buzzard (*Buteo buteo*) in the Leiden Museum, "hardly two of which are alike." The individuality of the male ruffs is famous, each an artistic unity by himself, but all the females, or reeves, seem to be identical.

The variability of living creatures is particularly conspicuous in certain cases, where there is what has been called "an epidemic of variations." This is well illustrated at present by the Fruit-fly *Drosophila*, which has given off numerous true-breeding mutations in the course of a few years. The Dutch botanist De Vries was led to recognize the frequency of mutations or brusque sports in Nature by a study of a stock of Lamarck's Evening Primrose (*Oenothera lamarckiana*) which he found as an escape in a potato-field near Amsterdam. It was "sporting" in an extraordinary way. Almost all its organs were varying, as if swayed by a restless internal tide. From this stock De Vries obtained, in a short time, half a dozen or more distinct varieties or elementary species, breeding true generation after generation. The Evening Primrose shows species in the making, and there are many other instances. Variability is a great fact of life. As Alfred Russel Wallace said: "Even Darwin did not realize how much and how universally wild species vary." The fountain of changes is welling forth abundantly.

(3) It may be said, however, that variability is all very well, but is it leading to anything? Are there any new

species appearing on the earth or in the sea? Part of the answer is that many true breeding varieties seem to be at present taking grip, like the dark-coloured sugar-birds (*Cœreba* or *Certhiola*) in certain West Indian islands, or like several dark varieties of moths in Britain.

(4) The reason why we do not see more of these novelties is that we are so short-lived. A mutation or brusque variation may *arise* all of a sudden, but it may take centuries for the novel strain to become a stable variety or species. The process of evolution in Nature is usually very slow. It may have taken a million years to fashion a feather, and organic evolution as a whole has probably been going on for more than five hundred million years. Yet some people expect to find the scarabee beetles of to-day, different from those in the ancient tombs of Egypt. The mills of evolution grind very slowly. If the span of our life were but a few minutes, we might be willing to give evidence that the small hand of the clock was stationary.

(5) It is sometimes said that there is no evidence of one species turning into another. In answer to this anti-evolutionist assertion several sets of facts must be noted. In the first place there are fossil series—e.g. of water-snails, where *A* and *Z* are very different, yet the intermediates form a continuous gradation, just like the stages in the growth or development of an individual. In the second place, while it is part of the definition of a species that it is *discontinuous*—itself and no other—there are often very striking intermediate forms that link one species to its nearest relative. In the third place, the objection suggests a view of evolution which errs in supposing that one species turns into another as if under a magician's wand. This is the error hinted at in the old word "transformism." What has usually happened is probably like this: variations arise which spread from their birthplace; as they spread they may continue varying in the same direction;

they may be isolated from the originative stock by some topographical change, such as the making of a peninsula into an island; in isolation there is a tendency to in-breeding which gives stability to the new stock; inter-crossing with the originative stock becomes rare and by and by it may become impossible. The new variety—a new species in the making—does not necessarily supplant the originative species, but environmental changes may occur which are fatal to the first species yet favourable to the second; and so the evolution goes on. An old species does not change into a new one; a new species arises as an offshoot from an old one; and various forms of isolation help greatly.

MAN AS EVOLUTIONIST

It is part of a biological education to go to flower-shows and dog-shows and all sorts of similar shows. For one sees how many true-breeding races man has established in a relatively short time, and one sees also that novelties are still emerging—new roses, new chrysanthemums, new fowls, and new dogs, many of them novelties to be proud of. All the races of pigeons have been derived from the Wild Rock Dove (*Columba livia*); all the fowls from the Indian Jungle Fowl (*Gallus bankiva*); all the pigs from two species of wild boar; all the dogs from wolves, probably of several species and perhaps occasionally helped by crossings with jackals. How the original taming and domestication came about we can only guess, for in most cases it is a prehistoric secret; but we know what man has continued to do. He starts from a variable animal, perhaps particularly variable because (as in dogs?) the pedigree may be multiple. Variations crop up which seem to man desirable; he pairs similar variants together and thus starts a strain. He continues doing three things—eliminating undesirables, bringing similar forms together,

and preventing intercrossing with other strains. A strain, confirmed by in-breeding, grows into a breed; and gradually a breed becomes a reliable race in which like usually begets like, such as Collie dogs, Polled-Angus cattle, White Leghorn fowls, Marquis wheat, Shirley poppies. It is not that man is a creator, for he can only operate with the variations that occur; he is rather like an artist who is supplied with fine materials which he arranges in new patterns.

With the further aid of Mendel's clue—a fundamental law of inheritance—he is now able to work even more rapidly and certainly than before, grafting one good quality after another on to a promising stock. Thus he can produce a wheat-race with heavy ears, early ripening, with fine flour and strong straw, and immunity to rust. Or he can secure a race of poultry laying over two hundred eggs in a year, or a race of cows that will produce not only more milk in less time, but milk with more butter and less water. It cannot be pretended that man's sifting and breeding methods are always attended with perfect success. Thus, hens are on the whole stupid birds compared with the lively experimental chicks; and no one can say that ordinary sheep fulfil the promise of the adventurous lambs. But that is partly because an oversheltered life tends to individual degeneration of wits; partly because man has selected his fowls for egg-laying qualities and palatability of flesh, not for their wits, his sheep for mutton and fleece, not for brains; and partly because he has in the course of generations consistently eliminated those hens and sheep that showed any tendency to be original and adventurous. Some of the breeds of dog that man has created seem to us semi-pathological products which Nature would do away with in a week. They are sometimes delicate, dull witted, even deformed, unnatural types, which man cherishes

because they please his or his customers' perverted taste. Against these we must place the large number of really fine and noble dogs.

ARTIFICIAL AND NATURAL SELECTION

What has happened during the domestication of animals and the cultivation of plants is closely parallel to what has occurred in Wild Nature in the evolution of new species. Variations that crop up are sifted and separated. Changing and entailing, sifting and segregating, these are the evolutionary factors in both cases. But the part that is played by the breeder is played in Wild Nature by the various forms of the struggle for existence, helped by isolation. The reason why man can work so quickly compared with Nature is that he can artificially bring similar forms together and artificially prevent cross-breeding. He can also extend his shield over small beginnings. But man has been a powerful factor in organic evolution, and there was great force in Darwin's question: If man has done so much in a short time, what may Nature not have done in a very long time?

Some enquirers find a difficulty in the fact that man's achievements in plant and animal breeding do not always last. In some cases, but only in some, there is a harking back to the original wild type. The reason for this is interesting, and may be illustrated in connection with the fur or pelage of rabbits. When one looks at a wild rabbit one sees a beautiful complexity, and there are eight hereditary factors that combine to produce this. In the course of artificial breeding it often happens that some of the colour-factors drop out of the inheritance—a common occurrence that cannot be explained here. If all the pigment-factors drop out, the individual young rabbit is an albino, and may be used to start a pure-breeding white race. But if the dropping out is partial there may

be yellowish, or blue, or black, or otherwise coloured rabbits. If some of the cards are lost in shuffling a pack there are likely to be some very poor "hands"! Now if the rabbits of a well-established colour-variety pair with others like themselves they breed true indefinitely; but if no care is taken, and if the pairing is promiscuous, there must be sooner or later a restoration of the original complexity of the wild rabbit; and this is called reversion. But in this case it is plain that the original wild rabbit had as regards colour a richer inheritance than any of the domesticated varieties we have mentioned. Disappointments with well-established breeds are usually due to crossing with dissimilar forms, or, in other words, to imperfect "isolation."

GAINS AND LOSSES DUE TO MAN

It is certain that man has enriched the world with his races of domesticated animals and cultivated plants. In many cases he has been able to pool the good qualities of several wild species. There is no reason why this kind of amelioration should not continue for ages yet to come. But there is another kind of change which has involved losses as well as gains; man has greatly altered the numerical proportions of the plants and animals in many countries, and he has exterminated many forms of life altogether. He has naturalized many useful plants and animals in countries to which they were strangers; but on the other hand he has had his share in deteriorating the fauna and flora of many lands. The number of different kinds of wild animals in Scotland has not decreased since Neolithic man settled there, some eight to ten thousand years ago, but there has been a deterioration of quality. Rabbits and sparrows, earthworms and caterpillars, rats and cockroaches, crickets and bugs, are but a poor exchange for the reindeer and the elk, the wolf and the bear, the lynx

and the beaver, the bustard and the crane. The same is true of many another country: the standard of the fauna is falling. For various reasons, some of them not man's fault, many fine creatures have disappeared for ever from the earth, creatures like the quagga and the Irish Deer, the Great Auk and Passenger Pigeon, but what man must be blamed for is the disturbing of the balance of Nature by short-sighted introductions, such as are illustrated by the rabbits in Australia and the sparrows in the States. Yet the hope is that the lesson of these mistakes is being learned, and that man's influence on the faunas and floras of the future will become increasingly ameliorative.

DOES EVOLUTION ALWAYS GO UP?

Some years ago a very distinguished spiritual ambassador to the United States was trying in a popular lecture to disarm a certain hostility to the evolutionary way of looking at things, pointing out, for instance, that there had been religious evolution among the Semites, as the Holy Scriptures indeed recorded.

But as he was proceeding with his argument and undoubtedly winning conviction, a strong voice suddenly hurled at the platform the defiance: "Ah, but that's not Evolution; that's what we call progress."

In a way, the interrupter was simply expressing his puzzled confusion of thought; yet in another way he had hold of a fact, that evolution may be down as well as up.

AN OVERWORKED WORD

There is progressive evolution, as when birds emerged from an extinct reptilian stock; and there is retrogressive evolution, as is illustrated in the origin of parasites from

independently living relatives, or of sedentary animals, like barnacles, from free-swimming ancestors.

Part of the confusion may be due to the way in which we overwork the word "evolution," for we apply it to many different processes of Becoming which have very little in common. Thus, as we have already said, the *cosmic* evolution of stellar systems is a process of change almost entirely different from the *organic* evolution of the modern horse from the four-fingered and three-toed little dawn horse, Eohippus. Or the *chemical* evolution of lead from one or other of several radio-active elements, such as thorium, is almost entirely different from the evolution of, say, language.

Similarly, *social* evolution is very different from the evolution of climates. Unless qualified by some prefix, the term "evolution" merely means a process of natural change such that something definitely new emerges. It is a continuous process of becoming in which the pre-conditions of the new are potentially resident in the old, always allowing, of course, that there may be give and take, action and reaction, between the emergent new organism and the environment.

DEGENERATION

In the realm of organisms, the evolving creature is always to be thought of as trading with time and trafficking with circumstance in an active, almost creative way. And if complex chemical elements—like the most complex known, uranium—arose from simpler ones—like the simplest known—hydrogen, it was by multiplications, permutations, and combinations of an active kind.

Evolution is never like emptying out the miscellaneous contents of a portmanteau and throwing them in again in another way, unless, indeed, there is some new idea in the repacking. In Biology the useful word "development,"

as of the chick within the egg, should always be kept apart from the word "evolution," such as the emergence of birds from a reptilian ancestry. Development means *individual* Becoming, while evolution means *racial* Becoming. But while they are quite different, they are correlated in subtle ways.

Fifty years ago, Sir Ray Lankester, till recently with us, delivered an important British Association lecture on "Degeneration: a chapter in Darwinism," in which he showed in his masterly way that organic evolution may be downwards as well as upwards. The same idea was emphasized about the same time by Dr. Anton Dohrn, for many years the Director of the Zoological Station at Naples.

It is a pity that the lesson brought home by these two eminent zoologists has been so often forgotten.

Lankester pointed out that some animal types reach a state of balance and may so remain for millions of years unchanged. Thus, the Lamp-shell *Lingula* and the Kingcrab *Limulus* attained perfection unthinkably long ago and have so remained. A second alternative, which he called elaboration, is illustrated by series of animals which show progressive intricacy or specialization of structure and progressive increase in control or harmony.

These are the two standards by which we judge whether one type is higher or lower than another. The technical terms are differentiation and integration, and they may be applied not only to living creatures but to mechanisms. Thus, the railway locomotive of to-day is more intricate and more controllable than George Stephenson's "Rocket" of a hundred years ago. It is more differentiated and more integrated.

Similarly, a Golden Eagle shows elaboration as compared with the first-known bird, *Archæopteryx*, which

had a long tail like a lizard's, a half-made wing, abdominal ribs like a crocodile's, and so forth.

CESSATION OF ACTIVITY

The third alternative is Degeneration, when the creature sinks back from the level which its ancestors had reached. It becomes suited to more easy-going conditions of life. This is most clearly illustrated when the individual type recapitulates the racial relapse in its individual life-history.

Thus, the common sedentary sea-squirts or Ascidians begin their life-history as free-swimming vigorous larvæ, somewhat tadpole-like in general structure. Soon, however, they settle down exhausted, and forthwith lose the tail, the supporting skeletal rod or notochord, the spinal cord, the eye and more besides. This is individual degeneration condensed into a few hours, but it represents a racial degeneration—a retrogressive evolution. So is it with the sedentary barnacles and with many parasites.

We must be careful, of course, not to confuse simplification with degeneration, for there may be progress by reducing as well as by increasing the number of parts. As Lankester said: "In Elaboration there is a new expression of form, corresponding to new perfection of work in the animal machine; in Degeneration there is suppression of form, corresponding to the cessation of work."

CAUSES OF DEGENERATION

Why should a race go back? One reason is a relapse into a life of greater ease, as is well seen in the degenerate guest-beetles which are too well treated by the White Ants in their stuffy termitaries. Sinking into sedentari-

ness is often risky; as Luther said: "When I rest, I rust."

Internal parasites often illustrate the economic ideal of "complete material well-being"—food in abundance and available without exertions, a comfortable, restful environment without tonic stimuli such as light, an absence of enemies and little risk of dislodgement—everything for nothing, in short.

The nemesis is a bathos of degeneracy, except that the parasites, being products of evolution, show useful adaptations to their inglorious lot. As George Meredith tersely said: "Behold the life of ease, it drifts." Sometimes, however, the degeneration seems to have resulted from some constitutional defect, such as the absence of kidneys in sea-squirts. This will tend to be aggravated by inbreeding.

RETROGRESSION IN MANKIND

Compared with tentative men, *Homo sapiens* shows an advance in many directions, especially in mind and brain. If this is not to be called progress, then it will be necessary to invent some other word. But the progress has often been chequered, and retrogressions have been many. When we think of the giant intellects of ancient Greece and what they achieved in widespread culture, are we not forced to regard the Dark Ages as in the main retrogressive?

No one now accepts the pride-saving theory that savages are all degenerate derivatives of more advanced races. There is more truth in the view that they represent lower levels in human evolution, that they are our "contemporary ancestors."

On the other hand, in certain conditions there has been degeneration, especially when in warm countries the struggle for existence has been too easy. When food is

procurable in abundance without much trouble, man is apt to slip back, and we see what Tennyson called "reversion, ever dragging evolution in the mud."

But it is not necessary to go to savages to find instances of retrogression. There is no law of Nature which compels a race to go downhill after it has reached a climax. Though that has often happened, there is no proof of its necessity. On the other hand, there is no certainty that progressive human evolution must continue. What is oftenest plain among civilized peoples is partial and temporary retrogression amid a general advance.

The retrogression is oftenest associated with conditions that are too easy-going, with a loss of the spirit of adventure and a weakening of moral fibre, and with changes which lessen the wholesome sifting without which there can be no steady advance or even a secure holding fast to that which has been already gained.

We cannot escape the urgency of Herbert Spencer's dilemma of civilization: "The law that each creature shall take the benefits and the evils of its own nature has been the law under which life has evolved thus far. Any arrangement which, in a considerable degree, prevents superiority from profiting by the rewards of superiority, or shields inferiority from the evils it entails—any arrangements which tend to make it as well to be inferior as to be superior, are arrangements diametrically opposed to the progress of organization and the reaching of a higher life."

INTELLECTUAL BARNACLES

In many cases the degeneration is probably in individuals and communities rather than in the race; but the latter is apt to follow the former.

Fifty years ago, Lankester wrote: "Possibly we are all drifting, tending to the condition of intellectual Barnacles

or Ascidians. It is possible for us—just as the Ascidian throws away its tail and its eye and sinks into a quiescent state of inferiority—to reject the good gift of reason with which every child is born, and to degenerate into a contented life of material enjoyment accompanied by ignorance and superstition.”

We have been emphasizing in this chapter the fact that organic evolution is not necessarily progressive, but we must also emphasize the encouraging fact that *on the whole* evolution has been towards greater differentiation and integration.

There have been many extinctions (some of them very puzzling), many oddies (some of them very beautiful), and many retrogressions (some of them full of warning to man); but on the whole there has been an increase in the fulness and freedom of life and a trend towards the emancipation of mind. Why should we let this stop?

CHAPTER XLVII

DOES THE PAST DIE?

Willy-nilly, we are walking museums, carrying about a living collection of relics which prove our solidarity with the mammals. Even the anti-evolutionist is, as Walt Whitman said, stuccoed all over with quadrupeds.

The reason for this is something like momentum in organic evolution, for a structure that took ages to establish will persist long after it has outlived its usefulness. Just as man's clothes show buttons that do not function and buttonholes that do not open, so in our body there are vestigial structures, the dwindled relics of what were once much larger and actively in use. It is evident that "vestigial" is a better word than "rudimentary," for vestigial suggests dwindling, like disappearing footprints, whereas rudimentary might mean incipient. The electric organ in a skate's tail is probably an incipient or rudimentary organ with a future before it, but the vestige of a gill in the spiracle is dwindling.

Darwin compared vestigial organs to the unsounded letters in words, like the "o" in leopard, or the "b" in doubt; they are functionless and may be omitted without making any difference to the sound. Yet their disappearance would remove an interesting clue to the history of the word, for the "o" in leopard tells us that people once believed that carnivore to be a cross between a lion and a tiger. But the comparison of vestigial organs to vestigial letters in words breaks down in this respect, that the unsounded letters have not become any smaller than their functional neighbours.

Some museums do great service in exhibiting what may be called the evolution of mechanisms, such as

bicycles and steamships, railway locomotives and pianos. These exhibits show the gradual advance from stage to stage, and are very educative. One peculiarity about them that strikes the student of animal evolution is that they show so little trace of vestigial structures. The mechanisms that we mentioned are very intricate, but so far as we know they have almost no parts that are not of use. Whereas our body swarms with relics. Part of the reason for this difference is that as the mechanism is gradually improved from decade to decade, it is very severely criticized in reference to utility and economy. Another reason is that the machine is evolved from without by man, whereas the living creature is evolved from within and cannot shake off the hand of the past, which is, as a matter of fact, its inheritance.

On the other hand, when we pass from machines to clothing, where criticism or selection for utility and economy is less stringent, and where the changes are influenced by subtle factors like fashion and taste, we find many instances of vestigial structures. Thus, in a man's jacket everyone is familiar with buttons at the wrist that are never used, though there are often three on each side. In most cases they cannot be unbuttoned, yet they are the relics of buttons which used to be of use in folding back the sleeve. The same is illustrated by the buttons at the small of the back on a morning-coat, once used in fixing up the tails. As to buttonholes, they often make no pretence at being openable; they are quite vestigial.

In our body we carry about several scores of useless relics which tell us something about the past. Their persistence shows us that the past lives on within us, even in trivialities. But many of these vestiges are little details which are unfamiliar except to the anatomist, so we must content ourselves with selecting a few of the most striking.

In the corner of our eye there is a little fold, between

the eyeball and the red "caruncle" at the inner angle of the eye. It is larger in some of us than in others; it is larger in some races than in others; it sometimes contains a thin slip of gristle or cartilage. Now there is no doubt as to the meaning of this fold which anyone can see in the looking-glass; it is a dwindled relic of the third eyelid which is present in most mammals, as also in birds. It can be well seen in the cat and the rabbit, and it is used to clean the front of the eye. As it is flicked across the eye and back again, it is called the nictitating (which means winking) membrane. It is present in most mammals, as we have said, but it is absent in whales, monkeys, apes, and man. Its absence in whales is natural enough, since the front of the eye in these aquatic mammals is always being washed with water. So the third eyelid in Cetaceans has dwindled away in the course of ages, the reason probably being that many structures in the body are continually fluctuating in size from generation to generation, and that minus variations in a useless structure would tend to survive rather than plus ones. And if it be asked why there should be any advantage in the minus variations of a useless structure, part of the answer is that the dwindling means some economy, and that a useless organ is apt to go wrong. We know this in the case of our vermiform appendix, which, if not useless, is at any rate easily dispensed with. We also know that functionless members of a community are apt to go wrong. But why should the third eyelid have disappeared in the case of monkeys, apes, and man, who certainly do not live in water? The probable answer is that in these types the upper eyelid has acquired (for some undiscovered reason) much greater mobility than in other mammals, and the third eyelid is not required.

A horse standing by the side of the street often moves its ear-trumpets, or ear-pinnæ, perhaps to locate the

approach of its master who has been delivering goods. Many mammals do this, and the movements seem to help in the localization of sounds. They are also emotional signals. But in man the ear-moving muscles are typically vestigial, the reason probably being, as before, that they have become quite useless. For man locates sounds in a more effective way by moving his whole head from side to side, or tilting it at an angle.

Yet most of us have come across a man who can move his ear as a whole; and in some cases great facility is acquired at the expense of time, and perhaps of energy, that might have been more profitably utilized. But these exceptionally gifted individuals are very interesting, for in the museum of their body they have three ear-moving muscles which are less vestigial than in more ordinary human beings. These exceptional individuals sometimes have an unusual mobility of facial muscles, including nasal muscles; and this is interesting because the muscles that move the ear-trumpet are derived from the same sheet of muscle as the muscles of expression. In various mammals, such as horse and dog, the movements of the ear form part of the language of expression. In the anthropoid apes, it may be noticed, the ear-muscles are as vestigial as in man; but in monkeys they are larger and can draw the ears backwards when the creatures are angry.

If we examine the skull of almost any mammal, a sheep's let us say, we see two openings far forward on the roof of the mouth. Naso-palatine openings they are called, for they lead from the front of the bony palate to a gristly scroll in the nasal chamber, which encloses a sense-organ, called the organ of Jacobsen, after the anatomist who discovered it. It is made of cells like those that occur on the smelling patches inside the nostril, and it is almost certainly an auxiliary olfactory organ. It has been called an outpost of the nose, and it is probably

very useful in helping animals to detect some unwholesome odoriferous ingredient—say a poisonous plant—in the food that they have taken into their mouth. Now this paired organ of Jacobsen began in reptiles and is well developed in many mammals. But in man it is a vestige, often disappearing altogether; and the two openings are closed. The same relic is to be found in the apes' museum.

In many mammals, such as rabbits, a large blind gut or cæcum grows out from the junction of the small intestine and the large. This serves to delay the slowly digesting vegetable food, which passes into the blind gut and comes back again. In the rabbit it is the largest organ in the body. But in man and apes there is no blind gut; what is called the cæcum is the dilated beginning of the large intestine. What is the largest part of the food-canal in the rabbit is represented in man by the little vermiform appendix, which certainly looks like a vestige. As everyone knows, it is the seat of inflammation in appendicitis; and it is possible that the frequency of this trouble is due to the relative uselessness of the structure concerned. Perhaps it should be mentioned that while the old-fashioned Half-Monkeys or Lemurs have an appendix, the true monkeys have none. Yet it is present in the anthropoid apes. The probable explanation is that monkeys diverged from apes very long ago, on an evolutionary line of their own, and probably lost entirely what persists as a vestige in apes and man.

The best catalogue of our museum is Professor R. Wiedersheim's *Structure of Man, an Index to his Past History* (1897), in which there is an annotated list of about ninety "retrogressively modified organs, wholly or in part functionless, some appearing in the embryo alone, others present throughout life constantly or inconstantly." "For the greater part these organs may be rightly termed vestigial."

About thirty have to do with the skeleton; about twenty have to do with the muscular system; the remaining forty concern all sorts of structures—nervous, vascular, and glandular. Perhaps the cataloguer made the most of his congenial task, for some of the relics appear to us somewhat dubious; but even if we reduced the catalogue by a half, we should still have a fine walking museum. As Osborn has put it: "Both in the muscular and skeletal systems we find organs so far on the down grade that they are mere pensioners of the body, drawing pay, i.e. nutrition, for past honourable services without performing any corresponding work." Among those that are continuing to dwindle to-day may be mentioned the little toe and the wisdom teeth. The hand of the past is upon us, both for good and ill.

To be kept apart, if possible, from vestigial organs which persist in adult life are structures that occur only in the course of embryonic development. The difference is that though they do not come to much, if to anything, they may be necessary stages in the building up of the body, just as a scaffolding is necessary in the construction of a house. Take an illustration. Some of the old-fashioned vertebrate animals, such as lancelets and lampreys, have no true backbone, but show a more primitive skeletal rod called the notochord. In the early development of the human embryo there is a transient notochord, which is practically unrepresented in the adult. Yet it may be of some developmental significance. Its persistence may be not only a necessary, but a useful, recapitulation of the racial evolution. Similarly, the visceral clefts or gill-clefts of the human embryo, which are recapitulative traces of a remote gill-breathing aquatic ancestry, may have some present-day developmental value, though only the first comes to much in the adult, where it forms the Eustachian tube from the ear-passage to the back of the mouth.

But apart from such possibly useful recapitulations, there are scores of clear-cut useless vestiges, for which we can offer no explanation except that they are persistent relics of ancestral structures which once were well developed and in active use.

Care should be taken to keep by themselves all those dwindling structures for which some function is still demonstrable. Thus we do not agree with the great anatomist to whom we have referred in including in the human museum the pineal body, which rises from the upper surface of the brain, for although it may be retrogressive in man as compared with its state in the New Zealand Lizard *Sphenodon*, where it is distinctly a third eye, it still seems to form part of our regulatory or hormone-making system, especially in youth. It seems a sad irony that a modern anatomist should rank as vestigial not only man's wisdom teeth, but the organ which Descartes regarded as the seat of the soul.

The cautious physiologist usually hesitates about calling the human vermiform appendix *functionless*, for it is difficult to prove a negative of this sort. A man can thrive without his spleen, but the organ is very important for all that. Yet the vermiform appendix does look as if it were a dwindling structure. In man it is shorter and smaller than in the gorilla, where it is about the thickness of a little finger and twice as long.

One must not allow oneself to be too much obsessed by the idea of the relics of the past that persist in our body and in our mind as well. It must be corrected by the fact that we inherit plus as well as minus structures, great legacies as well as debts, progressive structures (like our fore-brain) as well as vestiges of little more than historical interest. The hand of the past upon the present is living, not dead, and it points not only backwards but forwards!

WHAT IS THE ORIGIN OF THE NEW?

There is no problem more intimate, more momentous, or more elusive than the origin of the new. In other words, the central problem in biological evolution is the origin of variations, whether they be brusque mutations or graduated fluctuations. They form the raw materials of possible evolution—a weeping willow, an Angora rabbit, an albino goldfish, a variegated bay-tree, a hairless dog, a tailless cat, a wonder-horse whose mane reaches the ground, a snap-dragon with unusually deep-green in its leaves, a wood-snail without bands on its shell, a pigeon with extra feathers on its tail, a ruff whose plumage is uniquely original, a waltzing mouse that dances round in circles, a wheat plant with an extra row of grains, a trout with a bulldog-like snout, a waterhen with buff plumage and slender feathers, a horse with stripes on its withers, a lizard with a novel livery, a butterfly with an original heraldic pattern, and so on and so forth for ever and ever.

For this is one of the insignia of living organisms, that they vary from generation to generation. There is a creative impulse in organic evolution which finds little counterpart in the non-living realm unless it be when the rational chemist puts his finger in the pie and evokes all sorts of novel carbon compounds—a little creator in his way. We know, of course, that one radio-active element gives rise to another, as uranium to radium, and radium to lead; but these are strictly predetermined transmutations, and while there is some hint of spontaneity, there is more evidence of obligatoriness. It is in the world of life that we see Free Will conquering

Determinism; for it is characteristic of individuals to be unpredictable. No one can tell how the cat will jump, we say; and no one can tell whether a kitten may not be, in a kittenish way, a new creation.

We visit an exhibition of paintings, and we take for granted that if the pictures are works of art they will be in some measure new, even if the subject has been portrayed a score of times before. A work of art must be an expression of individuality, and there is some individuality in most organisms, except, indeed, in those that have become, in the course of ages, so perfectly harmonious that varying would be a contradiction in terms. They are faultlessly perfect, splendidly null. We mean creatures like the Pearly Nautilus and some of the Lamp-shells, whose architecture seems to have persisted unchanged for millions of years. Yet these conservative types are exceptional; in the vast majority of living creatures there is flux, though our lifetime is too short to allow us to appreciate the extent of the changefulness. Thus it is good for us to visit flower-shows, bird-shows, dog-shows, and the like, where we feel the pulse of life.

There is much to be learned from the interesting story of the new variety of mouse that appeared not many years ago on the island of Foula, twenty miles off Shetland, an island said to be the Ultima Thule of Tacitus. The gist of the story is that some adventurous or reckless representatives of the common Long-tailed Field Mouse (*Apodemus* or *Mus sylvaticus*) were stowaways on a fishing-smack, and established themselves on Fair Isle, off Shetland, where the women knit the beautiful woollen "jerseys." On the Fair Isle the new-comer mice varied, and as they had to breed among themselves, since there were no others there, there arose a new sub-species, with quite definite characters of its own, the Fair Isle Long-tailed Field Mouse (*Apodemus sylvaticus fridariensis*).

But history repeated itself, and some Fair Isle varieties were transported, all unawares of course, to Foula, a small island (twenty miles off) rising to a height of a thousand feet or so, and abundantly covered with tussocky grass. There again another novelty emerged, and with the help of inbreeding, in a new well-insulated haunt, there arose a new sub-species or true-breeding variety, *Apodemus fridariensis thuleo*. Now the point is that this sort of new emergence is occurring elsewhere, for evolution is going on—going on probably much more abundantly than can be observed by the busy naturalist.

Living creatures are very plastic, taking on novel features which are directly due to peculiarities of environment, food, and habits. These directly impressed “modifications” are very common, but it remains doubtful whether they are ever handed on by inheritance to the next generation. We do not wish to close this door or to deny the possibility of the transmission of these individually acquired characters or modifications, but it is quite certain that they do not supply the main crop of new departures on which evolution depends.

It is largely to Weismann’s clear thinking that we owe the idea that the novelties that form the raw material of evolution are due to disturbances and changes, permutations and rearrangements in the germ-cells. The germ-cell—a telescoped-down living creature—is the unconsciously creative artist, whose novelties are eventually subjected to Nature’s sifting.

These germ-cells are repositories of hereditary initiatives or factors, usually called “genes” nowadays, and there are many opportunities in the individual history of the germ-cells for shuffling these hereditary cards, so that novel and sometimes strange “hands” result. It is for the individual full-grown organism to play these “hands” for better and for worse.

It is also probable that deeply saturating influences of environment (e.g. climate), and of diet, and of habit, may penetrate through the body and pull the trigger of the germinal changefulness.

Thus with characteristic insight Weismann suggested long ago that deeply saturating environmental influences, e.g. of climate, and deeply penetrating changes of diet, e.g. those we now associate with vitamins, might serve as trigger-pulling stimuli to the natural changefulness of the germ-plasm—that is to say, the inheritance-carrying living matter of the egg-cells and the sperm-cells. The organism is shifted to a new climate and its body is slightly changed, but the novel influences may penetrate into the germ-cells and affect them along with the body—affect them to this extent at least, that their variability is prompted to expression. External changes seem sometimes to serve as the liberating stimuli of novelties or new departures.

As a particular case of environmental influence as a change-producer, we wish to refer to a suggestion made some few years ago by H. J. Muller, that radiations from the earth, or even cosmic rays, may have played a part in evoking new departures in organisms. Under the influence of X-rays and other radiations from radio-active substances in experimental conditions, Muller found that the crop of mutations in Fruit-flies was larger than usual. Normally there are some such radiations in natural conditions, and they may have been more abundant long ago when radio-active substances occurred in different proportions on the earth, or, in other words, before there was so much lead as there is now. For lead is a familiar end-product in the disintegration of radio-active elements such as uranium and thorium.

What Muller began has been carried a little farther by Olson and Lewis, J. B. S. Haldane, and others. Some

recent experiments by Hanson and Heys, in California and Colorado, go towards showing that there is an increased rate of mutation in flies exposed to an unusually high degree of natural radiation. It is an idea worth thinking over and worthy of persistent experiment, that natural radiation may supply and may have supplied some of the mutation-grist for the Natural Selection mill.

Yet when we allow for the demonstrable opportunities for shuffling the hereditary cards; and for what may follow from the mingling of the two half-packs of cards that combine at every fertilization, in plant and in animal, of an egg-cell by a sperm-cell; and for the change-evoking influence of deeply saturating changes, whether environmental, nutritional, or habitudinal—we do not feel at all sure that we have recognized enough to account for the flowing of the fountain of change, almost ceaseless in some organisms, though interrupted in others. Nothing is more characteristic of the world of life than the frequency of change from generation to generation. Perhaps, then, it is necessary to recognize that the germ-cell, as an implicit living organism, has as part of its true inwardness or intrinsic secret an urge towards experiments in fresh self-expression. In any case, it is certain that all living creatures—plants, animals, and men—are springs of novelty.

To some it may seem strange that in discussing the origin of the new we have not said more about novelties that are impressed on the individual by peculiarities of nurture. The reason is that the transmissibility of these “modifications” is uncertain. Goldfishes kept in complete darkness for three years become blind and the retina undergoes partial degeneration. This is an instance of a bodily change following directly on a peculiarity of nurture, and a hundred other examples could be given. We do not know at present that the induced blindness of the goldfishes has any effect on their offspring reared

from eggs developed in the light. An endeavour must be made to get more facts bearing on this question, and if the verdict should be, as the trend of research suggests, that individually acquired bodily modifications are not as such or in any representative degree transmitted to the offspring, there is the further question whether the individual experience counts for something *indirectly*, and for what.

Professor Loeb has shown that it is easy in various ways to produce in the offspring of the American Minnow (*Fundulus*) a percentage of blind forms. It is enough, for instance, to expose the newly fertilized eggs for a few hours to a temperature a little above freezing-point. This indicates plainly that it need not have been the lack of light that caused the blindness of certain cave fishes and salamanders.

Shinkishi Hatai has shown that long-continued exercise (90-180 days) produces in the white rat many striking changes. The heart, liver, and kidneys increase in weight by about twenty per cent. as compared with non-exercised rats similarly fed. Even the brain shows an average increase of about four per cent. Here again we have an example of bodily change produced as the direct result of a peculiarity in nurture. What needs to be known, and will eventually be known, is whether this sort of individual experience counts for anything racially. There can be no return to the old belief in the transmission of any and every individually acquired character, but it is probable that we shall discover by and by that individual experiences count for something in evolution.

CHAPTER XLIX

HAS EVERYTHING LIVING A USE?

For a long time it has been held that everything in the natural realm must have some use. This is the sort of idea that might have been expected in an age when people think more about use than beauty, when the first question is: Will it pay? At a time when man has been much concerned with mechanical devices, often extraordinarily ingenious, it is not unnatural that he should think of a living creature as something like an automatic machine. There cannot be useless parts in an effective machine; therefore, it was argued, there cannot be useless parts in a plant or an animal.

There is another reason for the strong impulse to seek out a use for every part of a plant or animal, for in the main every living creature is a bundle of adaptations or fitnesses. A great naturalist used to ask: When you take away all the fitnesses from a whale, how much is there left? Think of some of the whale's fitnesses. It is a truly wonderful list:

The torpedo-like shape, so well suited for cleaving the water; the frictionless skin and the absence of projecting structures like ear-trumpets; the flattened flukes of the tail, forming a powerful propeller that works well without going round; the balancing flippers; the valved nostrils high up on the back of the head; the blubber a foot thick which makes the marine giant more buoyant and keeps the precious animal heat from being lost in the cold water; the shortening of the neck and the soldering of its vertebræ together, for a long flexible neck would be very

awkward in deep diving; the sponginess of the big bones; the spacious chest and the huge lungs; the usual reduction of the offspring to one at a time; and the arrangements for giving the young one a big gulp of milk when it comes to its mother.

Now, these are only a few of the whale's many fitnesses; and it is the same with other animals, though some are more strikingly adapted than others. There is a good reason, then, for seeking to discover the use of the parts in a plant or animal.

Another reason for the search for uses is to be found in the way organs dwindle and perish when they have ceased to be active. It looks as if there were a principle of economy in living Nature; if an organ does not work, neither shall it eat. The whale has no use for hind limbs, and they have dwindled away and are deeply hidden in the body. Snakes have long since lost their legs, using the ribs instead, and the remnants that are seen in a few cases are very small indeed. It looks as if Nature was not very tolerant of the useless. One reason for this, in addition to the expense of keeping them up, is that useless and stagnant organs are apt to be weak spots, where disease or parasites may find a footing.

It is much easier to prove that a thing is useful than to prove it is useless; but it is very suspicious when several different uses are suggested for the same structure, and when none of them is backed up with facts. Take the case of the unicorn whale, the narwhal, which has the biggest tooth in the world, sometimes seven or eight feet long. There is usually only one, and it is for all practical purposes confined to the male. It is thicker than a tent-pole, and tapers to a sharp point. It is made of spirally twisted ivory, and it projects straight out in front of the upper jaw. Now, the narwhal itself is only about fifteen

feet long, so that the tooth is not only huge in itself, but huge compared with the size of its possessor. One of the rough jokes of the ancient Greeks was about a man with such a long nose that when his friends met him they used to say: "How are you both?" So, if the carpenter had been addressing the narwhal and not the walrus, he might have said: "How are you and your tooth?"

But when we ask what is the use of this great tooth no one seems to know. One authority says the male narwhals fence with their teeth; another says the tooth is used for breaking a breathing-hole in the ice; and a third says the narwhal uses his great tooth for spearing big fishes like skate. So we begin to wonder whether the extraordinary tusk has any use at all. Perhaps it is an expression of masculine exuberance, like the antlers of the stag or the tail of the peacock. If it is only a decoration it is a very costly one.

We know how railway trucks left on a slight slope sometimes begin to move, ever so slowly at first, then more quickly, then at high speed, till they come crashing into the buffers at the end of the siding. We say that they *gather momentum*, and the same sort of thing is illustrated among living creatures, especially when they are in a position of great security. When they are comparatively free from the pruning that struggle always means, they are apt to go too far in some particular direction. They gather momentum, and a structure may be exaggerated into uselessness. A common sea-urchin is covered with spines like those of a hedgehog, but stiffer and shorter. Each moves on a ball-and-socket joint, and the hundreds of them, like little stilts, may help in locomotion. They also form a protective armour. But in some sea-urchins the spines seem to have grown far too big; they are as thick as lead pencils; they are as long as the diameter of the shell; they are still protective, but they are very

heavy. If some change occurred, requiring less sluggish movement, these big spines might be worse than useless. They might be a fatal possession.

Similarly, many molluscs have shells far too thick to be useful, often with strange roughnesses and ridges, spines and knobs, for which no use can be suggested. The armour of some of the extinct giant ground-sloths, some as big as oxen, became preposterously thick. It looks as if useless structures were most readily tolerated in creatures that have got into safe backwaters, away from the stress of the main stream. To change the metaphor, the struggle for existence tends to nip the useless in the bud.

There is nothing more beautiful in Nature than the colour of the withering leaves in autumn, which we might call the flowers of the forest, but there is no use in that magnificent brilliance. All that one can say is that the pigments are the products or the waste-products of what was once genuinely useful in the life of the tree. Similarly with the colouring matter in animals; it is only in some cases—like the oxygen-capturing red pigment of the blood—that we can say there is any clear utility. The beautiful, with which living Nature is crowded, is sometimes also useful; it may mean, for instance, good architecture or orderly growth; but in the majority of cases there is no usefulness, and we are not sorry. For it leads us to wonder whether beauty is not an expression of the spiritual essence of the world.

CHAPTER L

IS THERE CRUELTY IN NATURE?

Many good-hearted people are not a little troubled by things that go on in Wild Nature, so red in tooth and claw. They are somewhat ashamed of the system to which they belong. It has too much devil in it to be interpreted as a thought of God. Indeed, there is a sentence attributed to Aristotle which asks whether Nature is not rather demonic than divine.

The nightmare of Nature's wildness, ruthlessness, cruelty, wastefulness, and amorality is by no means confined to the sentimental, for the most powerful indictments are probably those to be found in John Stuart Mill's famous essay on "Nature," and in William James's still better known, "Is Life Worth Living?" Let us think quietly over "the cruelty of Nature."

The system of Animate Nature is evolved on the scheme or plan that many animals and a few plants use other organisms as food. The grass becomes the hare, and the hare the fox. We can, indeed, think of a wholly vegetarian world, the plants ultimately dependent on air, water, and salts; but it would not be the adventurous, resolute Wild Nature that we love. No one can deny that killing and eating another living creature—even another animal—is a ceaseless occurrence in Nature, but it does not necessarily involve pain. The rapidity of the killing is often masterly. The death-crisis of a mouse killed by a rattlesnake was thirteen seconds; that of a thrush killed by a Golden Eagle was even less! No doubt there are some terrible scenes, for instance, when two lions fall upon an antelope, or when the wolves close in upon a deer, but these are exceptional. And did not Livingstone tell us that he felt

no pain when the lion held him in its jaws? Alfred Russel Wallace had wide experience of life as it is lived in Nature, and he wrote :

Animals are spared from the pain of anticipating death; violent deaths, if not too prolonged, are painless and easy; neither do those which die of cold or hunger suffer much; the popular idea of the struggle for existence entailing misery and pain on the animal world is the reverse of the truth.

The only people who have any right to speak about the cruelty of Nature are the thoroughgoing vegetarians—all honour to them and more humour. But those who are against all killing of animals, and therefore charge Nature with cruelty, must be more than vegetarians. They must abstain from setting traps for mice or laying poison for rats; they must do without furs, of course, and even, we suspect, abstain from buying an eiderdown quilt for the baby. As for fly-papers, they are anathema; and if we blame Nature, dare we kill a snake? We like Darwin's common sense: "When we reflect on this struggle, we may console ourselves with the full belief that the war of Nature is not incessant, that no fear is felt, that death is generally prompt, and that the vigorous, the healthy, and the happy survive and multiply."

In the strict sense cruelty implies the enjoyment of the infliction of unnecessary pain, and there are at the most very few instances of this subtlety among even the highest animals. We have seen a buck antelope chasing and goring an upstart of his kin till the rival dripped with blood. There may have been pain here, especially afterwards, but there was no cruelty in the senior's severe punishment. We do not go the length of saying that "every prospect pleases and only man is vile," for there are some wild ongoing in Nature; but we are inclined to think that man has a monopoly of cruelty.

One of the difficult cases is the cat's playing with the

mouse, but even that familiar sight is not a clear instance of cruelty, as we have previously indicated. A caution to be kept in mind, moreover, is that domesticated and captive animals often develop unpleasant ways, for which man, not Nature, is responsible. And another caution is our ignorance of the gamut of pain. A wasp curtailed of half its body will continue nonchalantly sipping jam, and the legged part of an ant may work for hours after losing all the rest! We do not think John Stuart Mill and William James were well acquainted with Animate Nature, else they would not have written as they did.

But part of the difficulty is due to an inability to look at things in cosmic and evolutionist perspective. Such a wise old naturalist as John Burroughs surprised one by writing: "What savagery, what thwarting and delays, what carnage and suffering, what an absence of all that we mean by intelligent planning and oversight, of love, fatherhood."

But this is a nightmare view, to be corrected by Darwin's and Wallace's insight. There are scenes in the animal world that grate on our sensibilities, but we have to realize that the balance and progressiveness of Nature involve and require bloodshed. There is no progress without sifting.

One loses patience with a namby-pamby view of the world, discoloured by the sight of blood. Much saner and much more accurate was Wallace's: "On the whole, then, we may conclude that the popular idea of the struggle for existence entailing misery and pain on the animal world is the very reverse of the truth. What it really brings about is the maximum of life and of the enjoyment of life, with the minimum of suffering and pain."

CHAPTER LI

WHENCE CAME MAN?

Sir Arthur Keith's careful, dignified, and happily phrased presidential address to the British Association at Leeds aroused many thoughts in many minds. As expert anatomist, who has given most of his energetic life to the study of man's ancestry, the president did service in telling us how scientific judgment stands to-day in regard to Darwin's conclusion that man arose from an extinct stock common to him and to the Anthropoid Apes, who diverged in a different direction. Very wisely, on a responsible occasion like that which he adorned, Sir Arthur put restraint on himself, and, except on two points, kept away from the uncertainties which concern the operative factors, and gave all his strength to an emphasis on the fact that man is solidary with the highest mammals. Make scientific hypothesis we must, probing and enquiring, if we are to be true to the height of our calling, but there are times to speculate and times to refrain from speculation. So the president did well, we think, in confining himself in the main to the question: Was Darwin justified in concluding that man sprang from a stock common to the Anthropoid Apes and to him? Sir Arthur Keith's answer was that Darwin's conclusion has been corroborated by all that has been discovered since 1871, when the *Descent of Man* was published. Some of the gaps between *Homo sapiens* and a generalized Primate have been filled. How Darwin would have enjoyed scrutinizing the relics of Pithecanthropus the Erect, the Heidelberg Hominid, and the Piltdown tentative man, the many skeletons of Neanderthal Homo, the Rhodesian man, and so with the other discoveries which lessen what with his charac-

teristic frankness he called "the great break in the organic chain between man and his nearest allies." But besides the direct historical evidence which these relics afford, there are striking confirmations,—from the blood tests of blood-relationship between man and apes, from the samenesses in the early development of the two divergent branches of the common stem, besides quaint resemblances in maternal instincts and in infantile ways.

Sir Richard Owen, who was president of the British Association's meeting at Leeds sixty-nine years ago, was on the non-evolution side, and emphasized, not without reason, man's apartness; yet even he has spoken of the "all-pervading similitude of structure" between man's body and that of the apes. Our knowledge of this similitude has greatly increased since Owen's and Darwin's time; and it seems fair to say that every important structure in man's brain is represented in the anthropoid's, even into unsuspected detail. But in modern man the significant structures have been raised, as it were, to a higher power. The divergence of the Hominoid and the Anthropoid branches from their common stem occurred in the Miocene period, perhaps a million years ago, so we need not blush about our poor relations; but there is reason to believe in a saltatory variation—a mutation of magnitude—which lifted the early Hominoids from the pit whence they were digged and the rocks whence they were hewn.

Yet we need not over-emphasize the probability that early man was a saltatory variation or genius, for the researches of Professor Elliot Smith have disclosed a graduated cerebral improvement from tree-shrew and spectral tarsier to lemur and marmoset, and thence to monkey and ape—an improvement correlated with arboreal life and involving in particular the brain areas concerned with vision, manipulation, and attention.

When tentative men came to the ground after their arboreal apprenticeship, the premium was still more emphatically on brains rather than on brawn. As Sir Ray Lankester pointed out many years ago, there was in Miocene times, for some unknown reason, a great increase in the size of the brain in several orders of mammals; but besides this general advance there was the particular trend, emphasized by Elliot Smith, which brought success to the visualizers, manipulators, and conversationalists! When the human brain is compared with the gorilla's, the great increase in the cortex affects chiefly the areas concerned with muscular skill, speech, and the comprehension of speech; and these are the three areas which are the last to reach their full development in the human child. We cannot reverse the drama and prove man's origin, but increase of knowledge consistently strengthens Darwin's argument and makes it irresistible.

Sir Arthur Keith made confession of the mistake of earlier evolutionists in looking for and picturing a straight line of human descent, leading back to a generalized fossil ancestor common to Hominoids and Anthropoids. There are not as yet many relics all told, but what they indicate is a zigzag line. Thus it is generally allowed nowadays that Neanderthal Man was no direct ancestor of ours, but an offshoot from a stem which also gave rise to the more permanently successful *Homo sapiens* species. So it has been throughout man's ascent and in most other fields of organic evolution as well. We get the impression of a branching staircase, of a cymose inflorescence, of a "sifting-out process."

Two or three millions of years ago the Primate stem sent out its first tentative branches, and the result was a tangle of monkeys. Some of these have been eliminated, many persist to this day—on the whole a merry crew.

But after giving off the New World monkeys, and by and by the Old World monkeys, the main stem (if we dare so speak when fossils are so few) grew on. It gave off the lower Anthropoid Apes, represented by the gibbon and siamang of to-day; it split in the Miocene into the branch of the higher Anthropoid Apes and the branch of Hominoids. From the latter, without haste, without rest, and sometimes leading to nothing, more lower branches were probably given off; at length there appeared those of the "tentative men," such as *Pithecanthropus* from Java and *Eoanthropus* from the Sussex Weald. At last came *Homo*, but even among his different species there was a continuance of the same sifting. Thus the Neanderthal people, who shared in the struggle, failed to enter into the promises. So we get the impression not so much of "man sprung from a monkey," but rather of man as the outcome of ages of groaning and travailing, of tentatives and testings. Can we wonder that the philosophically minded are inclined not only to see man in the light of evolution, but to see organic evolution in the light of man?

Whatever be our view of the factors operative in man's emergence, which Keith summed up as "biological forces," to which we personally should add psychical and social influences, to which Alfred Russel Wallace insisted, rightly or wrongly, in adding "spiritual influxes," we are bound to think of the agelong process as one that included the possibility of psalmist and prophet, of Aristotle and Plato, Shakespeare and Beethoven, Newton and Darwin. Organic evolution is a continuous process of Becoming, and it seems clearest to believe that there is nothing in the end which was not also in kind in the beginning. Thus as evolutionists we are led to the old conclusion that in the beginning was mind, and in it was life, and the life was the light of men.

We must be loyal to what seems to be a fact that man emerged gradually from a stock common to him and to the anthropoids ; but we must be loyal to other facts as well, and we must refrain from hurrying to conclusions in regard to the factors that may have operated in the marvellous ascent. Nothing that science knows is against philosophically or religiously interpreting the "humble primate animal" as on the way towards the fulfilment of a Divine purpose.

THE QUESTION OF QUESTIONS:
IS THERE PURPOSE IN EVOLUTION?

Age after age, and often from the depths of human nature, the question has arisen whether there is some transcendental Purpose in the making of the world. Is there some recondite meaning in it all, and if so, can we get any glimpse of what it is? More especially, is it legitimate to say that Nature is Nature for a Purpose? Was there a Purpose, or something dimly analogous to a Purpose, in the origination of the process of Evolution? Is Evolution permeated by or immediately controlled by Purpose? Or does it simply express a purpose which determined its direction from the first? We know a little about the tactics of Evolution, but is there a strategy? If not, why are we always groping after it?

It is evident enough that Science as such never asks whether there is a purpose in Evolution. That is not its *métier*, nor is the question answerable by its methods. The question is philosophical or religious. Science asks What? Whence? How? and Whither? but never the deeper "Why?" Yet it is possible that Science may make contributions which help us towards a synoptic or philosophical answer, if we are inclined to the search.

But while Science does not enquire into ultimate Purpose, it is perhaps useful to delay a little to notice that the general idea of purpose is legitimate in scientific enquiry, and cannot be dispensed with. We may avoid the word, but we cannot do without the idea. It may be enough to give one illustration—from Ecology, where the issue is clearest.

PURPOSE AS A FACTOR IN EVERYDAY LIFE

Of many a human day's work it is impossible to give a scientific description without taking account of the man's purpose. There is a forward looking, often warmed with emotion, that leads him to adjust his actions towards an end in the future. The purpose is a *vera causa* with hands and feet. An omniscient chemist might make a ledger of all the oxidations and reductions, hydrations and dehydrations, fermentations and adsorptions, that bring a lecturer to a particular platform; and an omniscient physiologist might tell of all the nerve impulses and muscle contractions, sensory stimuli and conditioned reflexes, and so on and so forth, that were concerned in the translocation; yet, after all, the appearance of the lecturer cannot be accounted for unless his purpose be recognized. In many human activities there is actually operative purpose—often conceptual, sometimes perceptual, often habitual, sometimes only a flash; but some sort of purpose there often is.

Similarly with many activities among higher animals, we cannot make sense of them scientifically unless we admit an operative perceptual purpose. Even though it be only a mental picture coloured by desire, it counts. The chimpanzee whittles a stick with its teeth till it is slender enough to fit into the hollow of a bamboo rod, making out of two sticks one long enough to reach the desired fruit outside the cage. A dog goes off for a mile along the highway to reach a spot where it was balked of a rabbit yesterday. The beavers spend weeks of co-operative industry in cutting a canal which is of little use until it is finished. Among higher animals there is perceptual purpose, and it counts. There is purposeful behaviour, comparable to our own, though much simpler.

When we pass to predominantly instinctive animals,

our description becomes less convincing, but that is partly because we have not as yet enough of information, though partly because man finds instinct foreign to his experience. Some worker-bees resting in the hive are roused by the nectar dance in which a successful incomer indulges on the honeycomb; they crowd around her, get the olfactory clue, of, say, clover, and off they go on the search. Some tailor-ants take their grubs in their mouths and dab them like animated gum-bottles against leaves held close together, so that these are firmly fastened with the silken threads which the larvæ produce. A Queensland spider hangs itself on a thread from a twig, and makes a short lasso with a viscid globule at the end, which it throws dexterously on a passing moth, afterwards drawn in and sucked. There are hundreds of such cases, requiring, of course, very careful discussion, but our point at present is simply that they are more than suggestive of a low grade of half-automatized purposiveness. The terminology will come right by and by, but is there not in many cases, until the automatization goes very far, something of the nature of a consciously bent bow of endeavour, some instinctive purposiveness, though we may not dare say purposefulness. Even when the racial automatization has gone very far, as it often does, we must not forget the long period during which the creature was testing its inborn inspirations, and playing its hand of hereditary cards. May we not say that there is a good case for believing in instinctive purposiveness?

Some of our biological friends, for whose investigations we have due respect, even when we think their conclusions are erroneous, maintain that the word "purpose" does not belong to the scientific dictionary. We agree as regards transcendent purpose, which is obviously beyond Science, but we profoundly disagree as regards great stretches of animal behaviour, of which we cannot make sense without

the hypothesis that some subjective or psychical activity, analogous to our purposing, operates as a real factor. If this be granted for higher animals, the difficulty is to know where to stop; and here we should be patient. What is one to make of an individual starfish that tackles a small sea-urchin with one arm after another, and disarms it by wrenching off the snapping-blades or pedicellariæ, the result being that the aggressor can protrude its elastic stomach over its victim. And yet the starfish has not a single nerve-centre in its body, only strands and networks of nerve-cells. Purposeful, no; purposive, yes.

Passing to still simpler organisms, we need the concept of purpose less; but can we do without it altogether? Take the careful account Jennings gives of an amœba pursuing a smaller amœba, overtaking it, engulfing it, losing it, turning on its course, capturing it again, losing it again—and there the story stops. We must be careful, Spinoza said, not to be too sure of what the body as body may not do; and most of us shrink from giving the tendril-bearing Bryony or the insect-catching Fly-trap credit for “purpose,” even in inverted commas. On the other hand, there is much to be said for a temperate pan-psychism. If we were on the mud of the pond and minified a thousand times, while an amœba magnified a thousand times drew near with its eerie tank-like movement, it is not likely that we should act on the hypothesis that it had no purpose.

Thus we reach the idea, obvious but often ignored, that insurgent organisms share in their own evolution, not in the sense of working towards a racial ideal, for man alone is fit for that, but in the sense of endeavouring to make the most of things and to express themselves in obedience to the universal urge of life—the *urge for more*: more food, more room, more light, more love, more life. Life in evolution is interpenetrated with Purpose!

THE TELEOLOGICAL IDEA IN PHYSIOLOGY AND EMBRYOLOGY

So far, then, we have stated, without argument, the personal impression left by many happy years as field naturalist, that the concept of immediately operative purpose is indispensable. It is often conceptual purpose in man, perceptual in higher animals; it may be instinctive or merely organismal purposiveness; but some sort of purposing there is.

Now before we pass to our larger theme it may be useful to indicate that it is very difficult in physiology and in embryology to dispense with some form of the teleological idea. That is to say, the description is inadequate without reference to an end or outcome.

Turn for a minute or two, and very simply, to physiology. On a holiday we watch a crofter cultivating his fields and perhaps gathering a sparse harvest from the sea. What he does is self-contained and reasonable in itself. But on our way home we watch a busy operator in a shunting-room, doing nothing hour after hour but attending to signals and pulling levers. His activities are not intelligible except as part of an organization, and as making towards certain results, not always very immediate. So in some simple animals and simple corners of animals we may study activities, self-contained and self-justifying like the crofter's; but most activities in animals are incomprehensible except as contributory to the whole life of the integrate of which they form a part. Physiology requires to be teleological in this wide sense, that the working of the parts, like those of a machine, cannot be understood unless they are considered in relation to one another and in relation to the whole. This is soon supplemented by dynamical or chemico-physical, or by distinctively physiological, formulations; and it may be that the story is not completed without recognizing

psychical factors as well—the *esprit de corps*. How many kinds of formulations are necessary is a question for discussion—one, two, or three—but our present point is that the physiologist, even if mechanist, must start with recognizing the organism as teleological.

Another study in which the teleological idea seems indispensable, not as an operative factor, but as part of the story, is development. One can never forget watching the development of a translucent embryo, witnessing in the course of a day a long series of movements and differentiations. One focuses on the problem all one knows—about cell-divisions, laws of cell-arrangement, mutual pressures, metabolic gradients, liberations of the latent action of regulators and organizers; one thinks of the egg-cell rich in initiatives dating from a distant past, and one works with the idea of a succession of liberating stimuli from within and from without, and so on and so forth. But can we leave out of our description the fact that the development looks *as if it were* purposive, as when it moves circuitously towards a result, or when it builds up an organ only to break it down again, or when it stops, de-differentiates, and begins again. Without raising the question whether there is not always a psychobiosis as well as a bio-psychosis, we are simply asking the embryologist whether he can dispense with teleological description. It was Von Baer who said: "The whole course of development is nevertheless ruled and guided by the essential nature of the future organism"—a fact, he added, which may be demonstrated by observation. Those who are fond of the risky machine analogy in physiology must admit that it does not become easier in embryology, for the embryo-machine makes itself as it goes on, often takes itself in part or whole to bits and begins again, and often lays down before it finishes with itself a stock of little machines for the next season.

ADAPTATIONS

Romanes, who was a shrewd naturalist, once said that "wherever you tap Organic Nature it seems to flow with purpose." As he was a sound Darwinian, it is likely that he mentally italicized "*seems to*"; but he was alluding to a fact—the abundance of adaptations in organisms. For this must be taken as a fact of observation, however it may be biologically interpreted. All complex organisms are bundles of fitnesses, and it is worth re-reading Darwin's account of the numerous mutual adaptations of bee and orchis, partly to realize afresh what an eloquent fact adaptation is, and partly to notice that Darwin found it a little difficult not to talk like Paley. From the widespread fitnesses and their extraordinary nicety, Paley inferred the direct action of a Divine Artificer—an uncouthly materialistic picture. But the edge was taken off Paley's argument when Darwin showed that it was possible, in terms of variability, heredity, and selection, to give a naturalistic account of the way in which the orchis and the bee had come to be so well suited to one another. It remains possible, however, to think of a Creative Purpose that so endowed the primitive irreducibles that they included for all their descendants the capacity of evolving fitnesses. This wider concept of Creative Design is expressed in the words that Charles Kingsley put into Dame Nature's mouth, as she sat so puzzlingly at leisure: "You see I make things make themselves." Thus did the genius of the Creator save the evolving world from the shackles of determinism, and yet secure the climax in the first act of the drama.

Those who point out that the thousand-and-one adaptations are marvellous, and cannot have arisen by chance, are repeating Darwin's own words; but to use the word "chance" nowadays in its popular sense in this connection

is a verbal fallacy. There is very little fortuity in variation, and almost none in Natural Selection, which sifts those saying "Shibboleth" from those saying "Sibboleth."

DOES ORGANIC EVOLUTION EXPRESS A PURPOSE?

We turn now to the philosophical questions—if we only knew how to put them—Are there aspects of evolution that suggest an initial purpose? Has the whole been thought out and endowed in reference to an end? Is evolution the realization of a Creator's thought, or will, or imagination, or purpose? Of course, all our words are necessarily but adumbrations when we are thinking of "the mind that was in the beginning, without which there was nothing made that was made." Not absolutely beyond us, however, for that mind "was life, and the life was the light of men."

It does not seem to us to be even thinkable to try to *prove* scientifically that there must have been a plan in the Institution of the Order of Nature. That would be the fallacy of transcendent inference, with a conclusion far too big for the premises; and in any case, it is not what Science is after. A safer mood is to be patient and to care little what words are used so long as we do not lose the Open Secret that there is behind all Evolution a Supreme Reality, of whose Spirit it is an expression. "Un Dieu défini, c'est un dieu fini"—like the Divine Artificer. But age after age Science has helped man to a finer vision of Him in whom we live and move and have our being; and Science, with its newest and grandest world, may be able to help us even now, with contributions of fact and formulation, towards the answering of our philosophical or religious question: *Is there a Purpose in Evolution?*

Science submits numerous data which are eloquent when considered together. Attention has often been

drawn to the orderliness of Nature, that we live in a cosmos. The pseudo-concept of "a fortuitous concourse of atoms" is ready for burial. The fortuitous dwindles as Science grows. Yet while we admire the orderliness of Nature, it may be asked whether there could ever have been disorder in anything that lasted. So perhaps a better way of stating what is rather a consideration than an argument is just that Nature becomes increasingly intelligible, making scientific description more and more possible, extensively and intensively; and the fact of Science—of Science that could not have been if the Earth had been beclouded—is difficult to think round without assuming that in the beginning was Mind. As Aristotle used to say, there can be nothing in the end of a process which was not also present in kind in the beginning.

Of much of the orderliness of Nature, what can we say except that the order is *what must be*. Similarly we should beware of over-enthusiastic deductions from the practical omnipresence of beauty in Animate Nature. This is a big fact, but in the majority of cases, the beauty, defined as that which evokes the æsthetic emotion, has an *inevitable* objective basis. There is no alternative in many cases, for the beauty depends on the ripple-marks of orderly growth, or the by-products of orderly metabolism, or the outcome of strenuous curhythmic movement. The larger fact, we submit, is that the process of Organic Evolution should have been such that it evolved with singular patience, so to speak, a type of being who found in the qualities of natural objects not only a delight but an inspiration.

What often happens is that the beauty of living things becomes meat and drink to us. It sometimes fills our cup so generously that, straining at the end of our emotional reach, we become religious, overwhelmed by the sacredness of the testament of beauty. The beauty of

the world, especially of Animate Nature, is included in the well-thought-out plan; but we see this most clearly after we have drawn the conclusion to which it points. When we impatiently seize upon some puzzling conclusion of our temporary balance-sheets, e.g. that all the physical universe is like a clock running down, which would be more dispiriting if it were less leisurely, we are probably suffering, oftener than not, from insufficient data. As an authority, unembarrassed by opinion, said the other day, "Gain of entropy always means loss of information and nothing more."

We have to face a practical dilemma. On the one hand, there is the risk of shutting our eyes to obvious rays of light, like orderliness and beauty, and on the other there is the risk of trying to press too big a conclusion out of the premises. The order of Nature is doubtless greater than our greatest thought of it, yet there follows too facilely the misinference that it is all being purposefully kept in order now. The Divine Artificer has been exchanged for a Divine Bureaucrat. The beauty of Nature is greater than we have yet discovered, yet there follows too facilely the misinference that the Creator paints the lily and adorns the rose. The Divine Artificer has been exchanged for a Divine Decorator. This won't do, for our vision of God, which Science has its share in refining, cannot be out of harmony with a naturalistic description of the world—that is to say, with describing outcomes as the natural and necessary resultants, emergents if you like, of the verifiable operative factors resident in the material. It seems to us inconceivable that Science should ever go back from this ideal of naturalistic description; but that does not in the least imply that we need refrain from idealistic, transcendental, mystical, or religious *interpretation*—the only kind of interpretation there is.

We turn now, beyond orderliness and beauty, to some

other aspects of Evolution which suggest a Purpose in the unthinkable Beginning.

THE UNIQUENESS OF THE EARTH

Personally we cannot grapple with the thought that flits through our mind that our earth is extraordinarily unique. We are not sure that there is any place except the earth where there could be protoplasmic forms of life such as we know, and we need not delay over hypothetical forms of life which we cannot imagine. All the organisms we know require water in fluid form, and that restricts life to a narrow range of low temperature. Nine-tenths of the matter in the universe is at temperatures in comparison with which $1,000^{\circ}\text{C.}$ would be relatively cool. We do not know of many planets altogether, though there may be more than we know of; and while it is indeed difficult to believe that conscious life is restricted to the earth, we do not know of any other possible homes, unless Venus and Mars are possible.

PREPARATIONS IN THE INORGANIC WORLD

Preparation for prospective results is not a scientific concept, except in the doings of organisms, intelligent animals in particular, as when marmots store for the winter. Yet Professor L. J. Henderson, in his *Fitness of the Environment*, has indicated many features in the Inorganic World which look like preparations for organisms. At a certain time there came to be—given the antecedents there had to be—abundant supplies of carbon, hydrogen, and oxygen near the surface of the earth, and these are the fittest elements for originating diverse and durable chemical systems, including organisms. At a certain time there came to be—given the antecedents there had to be—a meteorological cycle of water, and in half a dozen ways this opened the doors to life.

We must recall the fallacy of inferring Providence from the considerate way in which great rivers flow past large towns; and it has been said that if there had not been abundant availability of carbon, hydrogen, and oxygen, and of liquid water, there might have been alternative organisms well prepared for by alternative environments. But we cannot imagine any alternative forms of life. So we may agree with Henderson that the primeval environment is "only fully intelligible, even when mechanically explained, as a preparation for the evolutionary process"—as, in short, telcological.

PREPARATIONS IN ORGANIC EVOLUTION

We have admitted that the idea of "preparation" is not scientific except when one is dealing with cases like a bird preparing a nest or a meal. Yet there is much in Organic Evolution that suggests prearrangements making subsequent steps of progress secure. It is salutary to be again reminded of the noble rivers running past the big towns, but there is more in it than that. The green plants make the breathable air; they make food enough to support themselves and the animal world; the continuance of life is almost unthinkable without bacteria; the welter of Plankton organisms makes fishes possible and fishermen too; perhaps the emergence of Amphibians, leading on to higher forms, was made possible by an almost unique property of water, that of having its maximum density a little above the freezing-point; and so on at length.

We are not saying that Plankton organisms evolved in order that there might be a Billingsgate; we are simply referring to the fact that the multitudinousness of the minute crustaceans in the sea, depending on the still greater multitudinousness of Infusorians and Diatoms, ensured the success of higher forms of life. Broad founda-

tions were laid which made a lofty superstructure possible. There is a *Systema Naturæ*; and it looks as if the whole of Evolution had been well thought out, as we say fumblingly. In other words, we ask whether naturalistic description and teleological interpretation are not complementary ways of looking at Nature. No doubt, if the first floor of the great edifice grew from the ground floor, and if the ground floor grew out of the foundations, and if there are automatic ways of preventing the superstructure from becoming top-heavy, and so on, there is no need for an intervening master of works; but as we dwell on this evolutionary idea we come to have a very high respect for the foundation stones, which the Creator laid.

CIRCUITOUSNESS IN EVOLUTION

Those who are in a hurry have sometimes said that if the *nisus* or urge of Organic Evolution was initiated with a Purpose, oriented towards a distant goal, namely man, it should have been more direct in its working out, whereas it is remarkable in its circuitousness. Working towards an end! yet spending a million years in fashioning a feather; working towards an end, yet filling the stage for millions of years with types and even races that have left not more than fossils behind. Yet it may be that this was part of the fine strategy! Millions of years of tentatives, but the outcome a stable, reliable, balanced *Systema Naturæ*, a fulcrum on which man can move the world. Struggles, and failures too, for millions of years, but with the result that the endeavour after well-being becomes a habit. Delays, eddies, retrogressions, blind alleys, and worse, yet Evolution is on the whole integrative. Delay matters little if it meant that the door of choice was kept open. Though automatization is one of Nature's methods, the process is more markedly a story of emancipations—as Lotze said, “an onward-advancing melody.”

Russell quotes, from Von Baer's essay on "Nature's most General Law in Development and Evolution," the conclusion that the ultimate law of all creative processes is "the progressive victory of spirit over matter." There must be, one cannot help thinking, some evolutionary urge or *nisus*, *élan*, or impulse, rather subtler than has been yet analysed into either mechanical or chemical or biological terms. We mean nothing mystical, but something more than tendencies to aggregate, to colloidify, to incorporate, to grow, to multiply, and so on, with all the involved catalysts, hormones, and organizers—we mean a psychical urge, the subjective side of endeavour. In any case, we see, with Emerson, the worm mounting through all the spires of form, striving to be man; and in man's nearer pedigree, through tentative men, beginning with the Chinese *Sinanthropus*, quaintly called the Man of Sin, we see a zigzagness as striking as the persistence.

PROGRESSIVE EVOLUTION

Evolution is sometimes backwards and sometimes in an eddy—neither suggestive of purpose. But on the whole Evolution discloses progressive differentiation and integration, the emergence of types with greater fulness and freedom, and increasing dominance of the mental aspect, a growing freedom of mind. There are successive syntheses that make things new—such as atom, molecule, micella, cell, multicellular organism, cerebrate animal, intelligent animal, man, society. There are successive emergences, as Lloyd Morgan calls them, more than merely additive resultants. There is what Smuts calls, not very euphoni-ously, a hierachy of wholes. The larger steps, such as living organism, intelligent animal, rational man, human society, imply that the evolutionary urge takes a new form, it is raised to a higher power, and that we thus need new descriptive formulæ. Whenever, for instance, there is a

genuine human society, a description in terms of individual units is inadequate; the social heritage *inter alia* has to be taken account of. So it is, we believe, with many of the larger steps in Evolution. Even water changed the whole world. From the teleological point of view, then, evolution may be described as a series of progressive syntheses, which allow of novel expressions of the richness inherent in reality.

CONSERVATISM IN EVOLUTION

Not to be overlooked, and with an interesting teleological suggestiveness, is what may be called the conservatism of Evolution. We have just been speaking of new departures, but there is also a tenacious holding fast of that which is good, even though the strands may enter into the fashioning of a quite novel fabric. Hæmoglobin, the valuable oxygen-capturing pigment of the blood, makes its first appearance in the Nemertines, unsegmented worms of low degree. Many higher animals are without it, but it was too good to lose; it is conserved along some lineage or other, till it comes to its own in Vertebrates. The two most important pigments are chlorophyll and hæmoglobin, the former doubtless with priority. Is it not significant that their molecules should show a remarkable resemblance in each having four pyrrol rings united by a single metallic atom, magnesium for chlorophyll, iron for hæmoglobin? The primitive mode of locomotion, called amœboid, appears very early; we see it still in our phagocytes, in many a young egg-cell, and in the growing end of a nerve-fibre as it feels its way out from the brain or spinal cord of the vertebrate embryo. There is a remarkable conservation of gains; the entail is not readily broken. Man is not only the Crown of Creation, he is also in some ways its Epitome. He is musical—partly because amphibians croaked 300,000,000 years ago; he is a painter—

partly because chamæleonic reptiles thrilled to colour; he is gentle—partly because mammals gave milk to their tender young.

We think of Evolution too unimaginatively. We do not, for instance, sufficiently realize the teleological interest of great trends that are, as it were, anticipatory of man's higher values—the true, the beautiful, and the good. For there are prolonged prehuman trends in favour of nimble wits, clear-headedness, and facing the facts; also trends in favour of beauty and its appreciation; also trends in favour of the primary virtues like courage and affection. T. H. Huxley notwithstanding, we discern a momentum in animal evolution which is in line with man's most progressive movements. What hope there is for man in what Julian Huxley has told us of the way in which some bird-mates engender psychical attractions which raise physical fondness to affection, and last when the honeymoon is no more than a memory, if that.

MAN—THE PRESENT CLIMAX OF CREATION

What is at present the climax of Evolution? Is it not represented by a civilized community of healthy-bodied, healthy-minded, kindly, good-looking people, with a noble social heritage which they use and enjoy, living industrious, prosperous, joyous lives, which are increasingly satisfactions in themselves, with a growing embodiment of the true, the beautiful, and the good, and with successors also healthy, wealthy, and wise? Can we say that the original purpose of the institution of the Order of Nature was to lead on to this and to what reasonably lies beyond? For there is no warrant for supposing that Evolution will soon stop. Is the climax fine enough to give some confidence in answering the question, which many brush aside as unanswerable: Was there a purpose in Evolution? Charles Darwin thought so when he was

writing the *Origin of Species*, when he said that he deserved to be called a theist; but gradually this conclusion weakened, and he said that he must be content to remain an Agnostic, deeply doubtful of man's ability to draw general conclusions on the subject. His cousin, Francis Galton, was almost equally immune to metaphysical speculation, but he seems to have believed in a recondite purpose in the Universe. As his biographer says: "Increased vigour of mind and body appeared to him the aim of the power which we seem to discern working obscurely, and as if with difficulty, behind the apparently blind forces of Nature."

The object of our discussion has been to ask whether this apparent blindness of Nature's workings in the realm of organisms is not largely a bogey. It is grotesque to call Organic Evolution "a chapter of accidents." The fortuitous has shrivelled before increased knowledge; there is much definiteness in organic variation; and Natural Selection is discriminate sifting in reference to an already established *Systema Naturæ*. We have also noted a number of features that are in harmony with the trans-scientific idea that the Order of Nature was originally endowed in a way that we should call, in human affairs, well thought out. There seems to be a steady, though inconceivably slow, advance of life from monad to man, and man—even now—is no anti-climax. Of course, one is thinking of man as a social being, man with his science and art, ethics and religion, all to be included as outcomes of the original institution of the Order of Nature, not of course in any wooden, portmanteauish way, but in a way that secures organismal freedom in more or less degree throughout. And if man be pictured as one of the ends of the sublimely patient process, or as an instalment of one of the ends, an end that crowns the work, it is not illegitimate to look backwards, just as biologically

minded birds might on their reptilian ancestors. The whole process of Evolution has been such that it has had as its highest outcome a human society at its best. We have become accustomed to consider man in the light of Evolution, solidary with the rest of creation, but do we often enough try to envisage Evolution in the light of man—of man at his best?

If, for various reasons which do not concern us just now, we are theists, we do not doubt the purposefulness of Evolution. That is part of what "believing in God" means. But our present study has kept to what is called the Natural Theology point of view, and our question has been: Is the idea of purpose congruent with the scientific facts?—nay more: Do the scientific facts in any way suggest the interpretation that Nature expresses a purpose? Our answer has been in the affirmative, and since the scientifically known System of Nature, being largely unconscious, cannot be credited with a purpose, we are led to think of a Creator's Purpose.

Soon, however, further difficulties arise. Has there been detailed guidance and control throughout? or was the whole outcome, including its freedom to evolve the new, implied in the unthinkable creative Origination of the Order of Nature?

The theory that there has been purposeful guidance throughout the ages has to face great difficulties. It suggests imperfections in the original irreducibles if subsequent spiritual influxes, as Alfred Russel Wallace called them, have been from time to time necessary to help things and organisms over difficult stiles. Moreover, the insinuation of operative transcendental factors is apt to mean a relapse in both religious and scientific development. As Dean Inge puts it: "Only a cosmos which seems to be sufficient to itself can be conceived of as having been created by God."

The other theory is that the purpose and urge were potentially expressed in the beginning, in the creative institution of the original Order of Nature, as a garden's beauty in its sown seeds. As Paul Janet says: "That which is precisely most worthy of God is to have made a Nature which creates itself." A Divine Purpose may have been realized in the world-process of endowing the original irreducibles with the capacity of progressively working out their destiny in a relatively free way, so that the evolution has from time to time a quality of creativity. It would be altogether unfair to this theory to charge it with the crudity of picturing a world launched into space in independence of the Creator. That *ex hypothesi* is one of the things God could not do; but in regard to His abiding relation with His creation, who is wise enough to speak?

But we would suggest that if there is a purposefulness behind Evolution, and if man is an instalment of one of the purposes, it may be our most urgent and practical duty to try to discern more of the great evolutionary trends so that we may assist in the fulfilment of more of the purpose. We must study the tactics, so that we may share more fully in the realization of the strategy.

EPILOGUE

EPILOGUE

THE WONDER OF THE WORLD

Many parts of the earth, with a representative fauna and flora and diversified scenery, seem very delightful to those at least who are healthy in mind and body, and unoppressed by care. Using the words of the Old Testament, they say: "The lines are fallen to us in pleasant places." This enjoyment of the country, this "love of Nature," may be experienced, of course, at many different levels; it is greater when it is well informed and continually appetised. It may be a somewhat humdrum contentment, or it may rise to the overwhelming joy of those who have disciplined themselves to see beauty, or to the consuming intellectual passion of those to whom everything is a mark of interrogation. But we need not labour the point, we wish to take for granted that to most able-bodied and healthy-minded men and women the outer world, in which they more or less live, is very interesting and pleasant. The giant Nature that carries them in its grasp is on the whole a likable, attractive, and friendly giant.

But many people rise beyond the joy of contemplating Nature, just as the Hebrew psalmists often did, and are able to say without any affectation that they have seen "the goodness of God in the land of the living." Without being in more than a simple way poets or seers they have attained to a religious view of Nature which is not only steadying, but a means of grace—an enrichment of life. In this epilogue we ask how this step may be taken by the student of Nature, and what warrant there is for it. On the Ruskin memorial stone at the foot of Derwent-water they carved part of his own confession of faith:

"The Spirit of God is around you in the air that you breathe and His glory in the light that you see; and in the fruitfulness of the earth and the joy of its creatures, He has written for you day by day His revelation and has granted you day by day your daily bread." To be able to say this with some sincerity would be to some people whom we know the greatest prize of life, so it is with responsible sympathy that we ask whether there are in the contemplation of Nature by itself any finger-posts pointing in the religious direction.

Sitting quietly in contemplation of Nature, or wrestling with its scientific problems, or enjoying its testament of beauty, we often find ourselves asking *what it all means*. The outer world is very fascinating, full of interest, crowded with beauty, very educative, and much more, but has it some meaning that does not meet the eye, is it expressive of any purpose? Scientifically we ask—*What? Whence? How?* perhaps even *Whither?* and, if our horizons of enquiry are not too ambitious, we obtain answers that are satisfactory—or, at least, increasingly satisfying. But if we ask *Why?* what can we say? This has always been one of the roots of religion.

Some people, for whom we have high respect, find no need for the question *Why?* Whether this position be due to a hyper-development of the scientific mood—to which the question of ultimate meaning or purpose is foreign—or whether it represents a carefully considered recoil from verbal solutions of a problem regarded as hopeless, as it is *ex hypothesi* to science; or whether it merely expresses preoccupation with science, art, and practical affairs, we do not know; the fact is that there are not a few men and women who do not feel any necessity for religion, in the sense in which Robert Bridges spoke of "the necessity of poetry." We have no superior attitude towards them, and they have no interest in what we say

or think in this connection. We are writing for men and women, like ourselves, who are dissatisfied and ill at ease without some belief in a spiritual meaning behind it all. We cannot help trying to make some sense of our experience as a whole (that is philosophy), and we personally cannot make any sense without belief in a Divine Purpose (that is religion). We are taking religion to mean a sending forth of tendrils towards a supersensuous or mystical reality, personalized in God, a reality which gives some meaning to the world and man's place in it. So far as we understand the question, religion is not worthy of the name unless it transcends the scientifically measurable or definable. Educated men to-day have to choose between a mystical religion or none at all.

Perhaps our enquiry will be better understood if we start with the disappointing statement that it does not seem to be intellectually sound to try to argue, as is so often said, "from Nature to Nature's God." For, if "God is a Spirit, infinite, eternal, and unchangeable in His Being, Wisdom, Power, Holiness, Justice, Goodness, and Truth"—surely the only kind of God who meets our case—then He is not to be scientifically inferred even from our wonderful world in which we live. What then can we hope for? We may discover in our enquiry (1) that much results from our study of Nature that impels us to search after God; (2) that there are in Nature some suggestions or hints of a Divine Purpose; and, in any case, (3) that the outer world as described by science is one in which the religious spirit can breathe more freely than seemed possible to our forefathers.

Those who have come to a glimpse of the Vision of God along other pathways, as from a study of Human History, or of man's moral nature, or of the search after God in the past, must not be impatient with us if we do not simply assume what they have attained, and proceed

at once to try to interpret Nature as a Divine Revelation. Perhaps that were the wiser course, but we are writing here for those, like ourselves, who are especially interested in the world without—the *outer* world in which it is man's privilege to live.

I. THE ORDERLINESS OF THE WORLD

One of man's deepest impressions of Nature is its orderliness. It was seeing order in the movements of the "Heavenly Bodies" that made science possible, and Poincaré points out that there might have been no science at all if the earth had been badly beclouded. The more science advances, the more orderly the world appears; and although the "Laws of Nature" are not of such great repute as they used to be, when men spoke of physical phenomena *obeying* them, it would be rather pedantic not to recognize that we live under a Reign of Law, meaning by law a formula summing up uniformities of sequence. Our world is a cosmos, not a phantasmagoria; and it is not fair to say that as man has made the laws to fit the majority of cases, an illusion of order results, for imperfect as his formulæ still are, they show this approximation to reality that they can be used as a basis for prediction and for practical action. Given three satisfactory observations of a comet, the astronomer can predict to a night the date of its return. We live in a world of dependable sequences—a world far removed from caprice. A famous essay in our childhood portrayed a world of chance—a nightmare of a world, where nothing could be "lippeden to," as Scots folk say; but the more science advances, the more the fortuitous shrivels and the more the power of prophecy increases. It will be remembered that two astronomers foretold the discovery of the planet Neptune; the modern chemists have anticipated the discovery of some of the rarer elements; and the Mendelian biologists

can not only count but actually portray their chickens before they are hatched.

No doubt the spectacle of the star-strewn sky is one of the grandest of object-lessons in the whole realm of Nature, and, though we cannot formulate a syllogism, we can understand what the poet meant by saying that "the undevout astronomer is mad." We suppose that it could not be other than it is in its general principles, but the fact remains that we live in an intelligible world. No doubt in the realm of organisms—the world of life—we have to deal with *individualities* and thus with some measure of unpredictability; but on the whole there is regularity. Even the human brain, the most intricate system in the world, has its laws, though they are as yet but dimly discerned. Even in the domain of things there are whispers of indeterminism, according to some modern physicists; but everywhere there is order. Personal accidents often cut us to the heart, and "a tear will blot out the sun," but it can hardly be taken as a serious difficulty in the way of a religious interpretation of Nature that there are occasional earthquakes or that the little homesteads on the low slopes of Vesuvius are periodically destroyed. So long as we are not personally concerned, all of us would say that a reliable world is a better place to live in than one of providential interventions. It was, we submit, a change for the better when the orderliness of the cosmos became a current thought among educated people. There was no bitterness in the poet's reproach: "Shall gravitation cease when *you* go by?"

We do not seek to deny the shadows on Nature's prospect, but it usually turns out that "vile man" is to blame. He has to pay heavy taxes for his freedom and for his follies. It is a defensible position that some diseases have opened up possibilities of greater health, that some wars have led to a more stable peace, and that some

other ills have brought greater good. Shadows there are, but the big fact about Nature is its luminosity!

"A lion's skin is never cheap," and no big rewarding idea becomes ours for nothing; so the impression of orderliness is not to be gained without effort. It is flooding modern man, like sunlight; but there was a slow dawn. To some extent we must recapitulate the historical evolution of science in our own individual development. The intricate multitudinousness of the stars on high is obvious, but their orderliness grows upon us as we scrutinize more carefully. The diversity of the ninety-two chemical elements (one still amissing!) is one's first impression—carbon, phosphorus, sulphur, gold, silver, lead, and so forth—the impression of orderliness comes later as a reward to those who understand that the elements are all spun of the same stuff, differing from one another in the number and behaviour of their electrons. Or again, what a gamut between the waves of huge wave-length used in broadcasting, and those of the light we see, and those of the light we do not see, and those of the rays used in radio-therapy, and so forth! yet all are electromagnetic radiations travelling at the same velocity of 186,300 miles per second.

One's first impression of living Nature—of the hedgerow, the tangled wood, the animals of the floor of the sea which the dredge tumbles upon the trawler's deck, the clouds of insects in the meadow, the avian population of a northern bird-berg—is rather of diversity and multifariousness than of order. But as we "scrutinize," to use Fabre's favourite word, we begin to see that we are dealing with a *system*—a *Systema Naturæ* of related forms of life, with a quivering web of interrelations in which nothing lives or dies to itself, in which a sparrow cannot fall to the ground without sending a throb through a wide circle. Take a single instance as a sort of diagram—all

these numerous kinds of roses, well-marked species breeding true. It turns out that in each cell of each plant there is a definite number of microscopic nuclear rods or chromosomes; but in one group of species the number is seven, in another fourteen, in another twenty-eight, and farther still. This is a straw which shows how the evolutionary wind has blown—in orderly advance.

We cannot, of course, all be naturalists, or astronomers, or chemists, and so forth—a fact we are suspiciously fond of reiterating—but we should all be willing to take a little trouble to learn to find our way about in the world in which we live—just as we take trouble to get to know our Paris, or our yacht, or our motor-car, or our picture-gallery, or our music. And the present point is that the endeavour is sure to be rewarded by a growing disclosure of the orderliness of Nature. The phrase “the Order of Nature” is often and rightly used to indicate the great system of which we form a part; we are using it here to mean also the *orderliness* of Nature, and our enquiry leads us to recognize this quality as characteristic of the *Systema Naturæ*. In the old-fashioned theological language of Ecclesiastes, the impression was stated in the words: “He has ordained all things by number and order and weight”; and whether we take this great theistic step or not, or having otherwise taken it find corroboration here, we are bound to say that this fascinating, attractive, stimulating world, which we call ours, has orderliness—a growing orderliness—at its very core. Whence came it? Leading authorities in modern physics tell us that it cannot be thought of as emerging from a fortuitous chaos. It is time that the unfortunate and unreal phrase, “a fortuitous concourse of atoms,” was buried deep. Even the aboriginal nebula was not *that*! Suns and stars are fierce crucibles, as terrific in intricacy as they are colossal in size, but they are not chaotic. Even the primeval nebular

mass, rich in potency, was a cosmos in its way—an implicit cosmos, with “mind” included in its promise. Thus we discern a finger-post on the pathway to reality, though outside the scientific confines, which indicates an original Divine Creation of the Order of Nature and its orderliness. But there is a deeper step still, surely legitimate philosophically, an enquiry into the possibility of there being science at all. For man is the outcome of the system and in science he justifies his Divine origin ! There is a fine suggestion in the words carved over the doorway of one of the science buildings in the University of California: “Open Thou mine eyes, that I may behold wondrous things out of Thy law.”

II. THE BEAUTY OF LIVING CREATURES

We picture a citizen of the world, with strongly rural, as well as urban, interests, sitting down in peace to enjoy the harvest of a quiet eye. All this is very pleasant, he says ; I have been immensely interested ; Nature is like a drama ; but what does it all mean ? Is there more here than meets the eye—more, I mean, than meets the eye of even the most penetrating observer ? Is there some reality behind the veil of sense ? What if there is a Divine Purpose (a phrase that we should call question-begging, if we were *arguing*) behind it all—behind it and me ?

We have supposed that the first revelation reached by our citizen of the world was the orderliness of Nature, a revelation gained by the exercise of the intelligence. Will not the second revelation be the Beauty of the World—a revelation reached by the senses and emotions ? We mean by the beautiful that quality in things and creatures that excites the æsthetic emotion, which stands apart from other emotional thrills and cannot be confused with any. “A thing of beauty is a joy for ever” ; this remains the best working definition of the beautiful ;

and the quality of beauty is characteristic of our world. Has this fact of beauty any meaning?

There is to most eyes and minds great beauty in mountains and moorland, in seas and rivers, but there is perhaps greater unanimity in regard to the beauty of plants and animals. When we free ourselves from conventional prejudice and the like, we must allow that all living creatures are beautiful, especially when we see them in their natural surroundings. We may be allowed to make exceptions for creatures that do not live a free life, for those few that are diseased or badly parasitized, for those that are half-made (usually hidden away), and for those that bear the marks of man's meddling fingers; but we are prepared to defend the thesis that all natural free-living independent creatures have this quality of beauty. No doubt there is easy beauty, like that of a peacock's tail, and difficult beauty, like that of the snake; but the artists, who are the makers of beauty, form a court of appeal for all such cases, and their verdict, so far as we have tried, is always in Nature's favour. In Animate Nature the beautiful is all but omnipresent, and it is one of the joys of life.

All healthy people feel the thrill of beauty in Nature, it is part of our human legacy; and we must include it if we are to think of the world whole. Think of the coral, the sea-lily, the butterfly, the fluorescent fronds of seaweed, the feathery moss, the cedar of Lebanon, the nautilus shell, the gemmeous dragonet, the humming-bird among the acacia branches, the sinuous ermine loping over the snow, the bluebells tinkling by the wayside as we pass—everywhere masterpieces of beauty. There is a sensory thrill throughout our body, for, as Wordsworth said, Our "heart with pleasure fills and dances with the daffodils." To our delight in forms that sing, colours that laugh, and movements that dance—and these in every hedgerow—

there are added enhancing perceptions of meaning, for we enjoy the beauty of the eagle in the air all the more as there flashes through our mind a thought of the fitness of the wings for flight. Then comes a halo of pleasant memories and associations, and finally a play of subtle ideas, such as a vicarious pride when we see humble forms of life bending materials to their purpose, like the chaffinch building its nest, or see love striking the harp of life with all its might, as in the jousting blackcock.

In some measure the beautiful is an expression of orderly development, such as the ripple-marks of growth on a shell, or the cross-bars on a hawk's feather; in some measure the beautiful is an index of harmonious living, from which the discordant has been sifted out—if it was ever present. It is interesting to notice that while man's most elaborate colour-combinations are not always happy, Nature's are always harmonies, and often shout for joy. In some measure, also, the beautiful among animals is an expression of vigorous exercise and strenuous endeavour, and in some measure again it is the mind shining through, pointing from afar to the superlatively beautiful woman "whose temple face is chiselled from within."

But what is this all about? That we live in a beautiful world; that this beauty is not a human illusion, but an intrinsic quality of things (with an objective basis); that we, as part of that same system of Nature, have a sympathetic appreciation of it; that it has been a human discipline for ages, an enhancement of life, a cultivation of the spirit; and that it may have religious value—that is to say, it may be so overwhelming that we need the idea of God if we are to make sense of it. We smile at the Hebrew poet who called the hippopotamus "the chief of the ways of God," but the blindness is with us and the vision was with him.

Begging the question again, the reader may say; and

we must simply plead guilty. But we are not *arguing* from mundane beauty to the Divine; we are simply pleading for a reasonable consideration of *the fact of beauty*. Just as the old thinker said, "The way of the eagle in the air is too wonderful for me," so the thrill of beauty is often so strong that we send tendrils beyond science and say, as in Ecclesiastes long ago: "He has made everything beautiful in its season." We are fumbling after what the physiological philosopher Lotze meant when he said that it would be great gain if we could look upon beauty "not as a stranger in the world, nor as a casual aspect of certain phenomena, but as the fortunate revelation of that principle which permeates all reality with its living activity."

III. THE PROGRESS OF THE WORLD

Science as science cannot tell us anything about *the* beginning, for the moment we speak of the beginning scientifically we are bound to think of something before that. Yet science leads us to particular beginnings, such as that of our solar system, or that of our earth, or that of our fauna and flora, or that of man. Now when we think of any of these particular beginnings and of the present-day phase of things we are bound to admit "progress." In the world of life, it is particularly clear that some such word as progress must be used to express the advance since the early days when living creatures were all so small that they were hidden in invisibility; or since the later days, perhaps five hundred million years ago, when all the animals were still backboneless; or since the much later days, perhaps a hundred million years ago, when there were as yet no flowers on the earth.

Even when we compare our present-day earth with its beginning, hundreds of millions of years ago, as a knot on a colossal prominence drawn out from a nebular sun,

we must use some word like advance or progress, for there was an increase of possibilities, especially as it began to become fit to be a cradle for living creatures.

Without haste, without rest, for hundreds of millions of years, there was an advancement of life, as judged by increasing intricacy or differentiation and by increasing control or integration. It is not merely that all things flow; it is that the stream of life flows uphill. Amid the ceaseless flux there has been advance; the changes are not those of a kaleidoscope, but, as Lotze said, "of an onward advancing melody." We are deliberately using the more human word "progress" instead of "evolution" because we are for the present emphasizing the general advance, say from worms to insects, from reptiles to birds, whereas the more scientific term "organic evolution" includes the entire process, with retrogressions as well as forward steps, with degenerations as well as increasing division of labour and mastery, with the withering away of great branches of the genealogical tree as well as new growths rising high.

It is not necessary to go into details, for the largest fact is the most eloquent, that for millions of years before there were any backboneed animals there were numerous types of backboneless, that after fishes there came amphibians, and after amphibians, reptiles, whence emerged birds and mammals until at length there arose man. To our impressions of order and beauty we must add progress. In our thought of our world and our place in it we must include this advance of life, which has, with occasional relapses, continued for hundreds of millions of years. With Emerson we see "the worm mounting through all the spires of form, striving to be man"; and this is still going on—in some measure. So we must not think of ourselves in any easy-going way, we who are the outcome of so long and intricate a process and the only living

creatures to understand at all. We strain at our intellectual tether; it is too wonderful for us; to "make sense" of progress we need God.

IV. THE EMANCIPATION OF MIND

We are supposing ourselves to be quietly contemplating Nature, not pressing for the moment the scientific questions *What? Whence? Whither? How?*, but seeking rather to get a glimpse of meaning in Nature; and part of our glimpse is the gradual emancipation of mind in the course of animal evolution. We must evade the long-lasting problem of the so-called relation between "body" and "mind," for it is enough for our present purpose that the bodily and the mental aspects, the objective and the subjective, the physiological and the psychological, are alike undeniable aspects of reality, closely bound up together, perhaps as inseparable as the convex and concave sides of a dome. But our point is this, that the mental life of feeling, willing, and thinking, which is a very slender rill in the lower animals, becomes a strong stream in birds and mammals, sometimes a torrent in man. This is the biggest fact in Organic Evolution—that "mind" becomes more and more dominant, until it becomes the measure that measures all. By no verbal jugglery can we derive mind from matter, for mind has no molecules, and we only know matter through mind, but the evolutionist pictures the mental life as coextensive with the material life, and sees it growing in power in the course of the millions of years. As a fact of observation we recognize that in the ascent of life mind comes to count for more and more. Not only does brain supplement brawn in securing mastery, but psychobiosis (MIND-body) becomes increasingly dominant over bio-psychosis (BODY-mind). And we have no reason to believe that the growing freedom of mind, which evolution indicates, is soon going to stop. We belong to a system in

which mind becomes more and more explicit, and though we cannot scientifically picture how the promise and potency of mind lay implicit in the apparently simple beginnings with which we start our cosmogony—the cooling earth, let us say—we cannot philosophically get away from Aristotle's conviction that there is nothing in the ending that was not also in kind in the beginning. We know that there is Reason in the ending, if ending we can speak of; so there must have been the analogue of Reason in the Beginning. Thus, at the limit of our intellectual tether again, we feel compelled—and it is a glad compulsion—to say with the most philosophical of the disciples: In the Beginning was Mind; and that Mind was with God; and the Mind was God.

V. IDEALS IN NATURE

Nature's music is often very grave, and sometimes it overwhelms us with its tragic note. Speaking for ourselves we cannot shut our eyes to the shadows in Nature, such as the extinction of noble forms of life—blotted out as though they had never been, leaving not even indirect descendants; the frequent severity of competition among living creatures and the frequency of commonplace little tragedies; the open door of parasitism and the horrors of the drifting "life of ease." We should have liked to throw the cold light of science on these shadows, for some of them, like the alleged "cruelty of Nature," are pseudo-difficulties; but let us look at the facts four-square. We have seen that Nature is penetrated by orderliness and beauty, by progressiveness and mentality; but we can take a further step. It is an open secret that there is much in Animate Nature that is congruent with human ideals. Thus in Wild Nature—away from man's interference—there is almost no disease. Microbes are oftener friends than foes;

parasites are seldom seriously deteriorative. Nature is all for health—an object-lesson to mankind. Moreover, in the evolution of animal life there has been a persistent rewarding of the clear-headed, of creatures that faced the facts, of the courageous and the kindly. The supreme rewards of survival and success have been attained by birds and mammals, pre-eminent in their self-subordination and altruism. Nature is far more for than against man's moral ideals!

VI. AS IF THERE WERE PURPOSE

We spoke of the naïveté of seeing the finger of Providence in the way so many great rivers run through so many big towns, but at a higher level we say: How providential are the properties of water in the service of life—we cannot think of life without it. A particular kind of creature is evolved—by long-drawn-out processes of varying and inheriting, selecting and isolating—in peculiar surroundings; and then we say: How well adapted that organism is to its environment! So indeed it is, but the environment had a potent rôle in making the organism what it now is.

While the world of life is crowded with admirable adaptations or fitnesses—the narrowest hinge in our hand, the ever-ready self-focusing camera of the eye, the coiling tendrils of the hedgerow bryony, the whole body of a flying bird, the way the orchis is suited to the bee and the bee to the orchis, the fatal fangs of a poisonous snake, a single pinion from an eagle with a million different parts, the Venus Fly-trap in the Carolina swamp, and the Sundew on the British moor, and so on everywhere—the old argument from masterpieces to a Master-artificer has ceased to appeal.

The world is packed with "Paley watches" of all sizes, going and ticking, masterpieces many of them, wellnigh perfect many of them, marvels of efficiency,

intricacy, and beauty—watches that grow and multiply, develop and evolve under our eyes. Can it be that the Divine Artificer has gone? The answer is that we can give a reasonable account of how the adaptations have come about by the co-operation of causes resident in the material itself; so that the old image of a Divine Artificer must be replaced by that of a Divine Creator who instituted the Order of Nature in apparently simple forms, sufficient unto themselves. We cannot think of Him instituting the beginnings so imperfectly that they were often afterwards needing His additional help, particularly when they came to difficult stiles in the evolutionary ascent. Creation, once begun, continued of itself; and this is the kernel idea of naturalistic Evolutionism. The detailed teleology of Paley has disappeared for ever; but its place is taken by a general teleology which thinks of the original Creation, i.e. the institution of the Order of Nature, as sufficient for all that has emerged from it in the long sequence of Jehovan days. We are, of course, just as children with these thoughts of Creation and Providence, but while we must rise above the idea of a Divine Artificer we must not think of the world as like a projectile launched on its trajectory from a giant's hand. The theological idea of Creation must include some idea of sustenance and indwelling power; as if, somehow, the Creator kept His work always in mind.

If the enquirer is to think resolutely he must, in our judgment, leave behind him the pre-scientific idea of the details of Nature being God's handiwork, replacing it by the idea of a Divine Institution or Creation of apparently simple beginnings, from which emerged all that we admire and enjoy—ourselves included. "Emerged," not as items from a well-packed portmanteau, not even as the parts of the flowering plant from the condensed seed, or the parts of the bird from within the egg, but

with a certain ever-newness and unpredictability. Living creatures emerged by creative evolution, in which they themselves shared.

Scientifically we cannot find room for the idea of *preparation*, for all the successive stages in the evolution-process arise, like those in the development of the embryo, from antecedent stages which lead up to them naturally and necessarily. The idea of preparation is human and personal; it is not a scientific concept.

And yet we feel that we are not doing justice to our general picture of the world unless we recognize that the earth gradually became fit to be a cradle and home of life; that water appeared early, with properties full of promise; that in early days there was on or near the earth's surface an abundant supply of materials yielding carbon, hydrogen, oxygen, and nitrogen—the “big four,” essential in the making of living matter; that matter often occurs in a colloidal state, apart from which we can hardly think of the possibility of protoplasmic life; that green plants build up simple inorganic materials into carbon compounds, food not only for themselves but for the animal world as well; that they made the oxygen of the air, which animals breathe; that minute organisms multiplied so abundantly that they afforded a stable basis for the vast superstructure that was gradually built; and so on, through and through. The Institution of the Order of Nature was, humanly speaking, *very well thought out*.

VII. THE AWESOMENESS OF NATURE

Simple people in olden times were often overwhelmed by the awesomeness of Nature—the solemnity of the mountains, the immensity of the changeful sea, the darkness of the great forest, the power of the cataract, the loneliness of the desert, and much more besides. Often they were afraid

and made their appeals, sometimes rising to pure religion, sometimes sinking to ignoble magic. This susceptibility to the awesome, which has often prompted religious activities—practical, emotional, and intellectual—is very marked in old literature, like that of the Nature-psalms. Has it an echo nowadays?—an echo to which we need not be ashamed to listen? Personally we are inclined to an emphatic “Yes.” There are many places in the world, like the Yosemite Valley, where we should be ashamed not to be awed; there are many sights, like the Milky Way, which, if they do not fill us with fear, may well fill us with reverence. And apart from sights, the world is full of facts that strike the semi-religious chord. The immensities of the universe or universes; the antiquity even of our earth; the indestructibilities and yet the flux; the fountains of energy in sun and star; the multitudinousness and the powerfulness of Life; the unfathomed subtleties of mind; the conquests that science has made, and yet its ignorance; and man, a reed shaken with the wind, yet a thinking reed, an infant crying in the night and yet the measurer of the whole, weighing even the stars in his balance. The end—and yet we dare not speak as if finality had been reached—crowns the work; we consider Man in the light of Evolution; but we also need to consider Evolution in the light of Man—the crowning wonder, most commanding of awe, making all Creation, with its long groaning and travailing, more clamant of reasonable interpretation.

Minor marvels, we say, disappear before science, but the *magnalia Naturæ* remain wonderful, i.e. making everything else more significant. The rainbow-marvel wanes, but we wonder still at the light. All knowledge, as Coleridge said, “begins and ends with wonder; but the first wonder is the child of ignorance, while the second is the parent of adoration.” When the half-gods go, the God may

arrive. In any case there is much in our world that fills us with reverence and awe. "Take the shoes from off thy feet, for the place on which thou standest is holy ground."

In this, our tentative, epilogue—written in all humility, but with a knowledge that the poor may sometimes help the poor—we have not been thinking much of those who already enjoy the Vision of God—gained perhaps from human history or from conscience or from a testament of wisdom, like that which culminates in Christianity. Yet perhaps even to them, what we have said may indicate that science, which only seeks to describe things and processes in terms of the empirical lowest common denominators, can have no radical quarrel with religion which seeks to interpret or enjoy in terms of a transcendental Greatest Common Measure. There is no conflict in principle, though there may be in regard to particular conclusions, and must be whenever there is trespass—which is often.

We have been writing for those who seek after some meaning in evolution, some answer to the question: Why? and our conclusion is that science as such does not forbid a religious answer. More than that, we think that a religious view is indicated by pondering over the orderliness of Nature, its beauty, its progressiveness, the increasing dominance of mind, the hints of ideals in Nature, the suggestion of preparations in the agelong advance to man, and the awesomeness everywhere when we look deep and high.

The history of religions seems to us to show that men became religious (along practical, emotional, or intellectual lines) when they struggled at the limits of their reach. Sometimes the Fates were too strong for them, and they prayed; sometimes joys and sorrows were too much for them, and they worshipped; sometimes the

intellectual problems were too overwhelming, and they could not "make sense" of things without "believing in God." So that, for many minds, there is a *necessity for religion*; and this has been our line of thought.

Yet religion includes more than doings, emotions, and ideas to which we are compelled at the end of our reach.

It means opening our whole nature to the influence of the Supreme Reality who is behind all; and if God is real, it is not unlikely that He will help us. Scientific knowledge is indispensable, but it is, as the schoolmen said, "evening knowledge," *cognitio vespertina*, cold and grey and shadowy; religious knowledge is "morning knowledge," *cognitio matutina*, when all is seen in the growing light of a new day. So we come back to the God of our fathers, whose name Jchovah was held to mean "I am that I am," but according to other scholars means "I will be what I will be"—the God of Evolution!

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